# Automobile Engineering

*A General Reference Work*

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION, CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION, STARTING, AND LIGHTING SYSTEMS, GARAGE DESIGN AND EQUIPMENT, WELDING, AND OTHER REPAIR METHODS

*Prepared by a Staff of*

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

*Illustrated with over Fifteen Hundred Engravings*

FIVE VOLUMES

AMERICAN TECHNICAL SOCIETY
CHICAGO
1917

# Authors and Collaborators

**CHARLES B. HAYWARD**

President and General Manager, The Stirling Press, New York City
Member, Society of Automobile Engineers
Member, The Aeronautical Society
Formerly Secretary, Society of Automobile Engineers
Formerly Engineering Editor, *The Automobile*

**C. T. ZIEGLER**

Automobile Engineer
With Inter-State Motor Company, Muncie, Indiana
Formerly Manager, The Ziegler Company, Chicago

**MORRIS A. HALL**

Formerly Managing Editor *Motor Life*, Editor *The Commercial Vehicle*, etc.
Author of "What Every Automobile Owner Should Know", "Motorists' First Aid Handbook", etc.
Member, Society of Automobile Engineers
Member, American Society of Mechanical Engineers

**DARWIN S. HATCH, B. S.**

Editor, *Motor Age*, Chicago
Formerly Managing Editor, *The Light Car*
Member, Society of Automobile Engineers
American Automobile Association

**GLENN M. HOBBS, Ph. D.**

Secretary and Educational Director, American School of Correspondence
Formerly Instructor in Physics, The University of Chicago
American Physical Society

**HERBERT L. CONNELL, B. S. E.**

Lecturer in Charge, Automobile Division, Milwaukee Central Continuation School
Editorial Representative, *Commercial Car Journal* and *Automobile Trade Journal*
Member, Society of Automobile Engineers
Member, Standards Committee of S. A. E.
Formerly Technical Editor, *The Light Car*

## Authors and Collaborators—(continued)

**HUGO DIEMER, M. E.**

Professor of Industrial Engineering, Pennsylvania State College
American Society of Mechanical Engineers

**HERBERT LADD TOWLE, B. A.**

Specialist in Technical Advertising
Member, Society of Automobile Engineers
Formerly Associate Editor, *The Automobile*

**ROBERT J. KEHL, M. E.**

Consulting Mechanical Engineer, Chicago
American Society of Mechanical Engineers

**EDMOND M. SIMON, B. S.**

Superintendent Union Malleable Iron Company, East Moline, Illinois

**EDWARD B. WAITE**

Formerly Dean and Head, Consulting Department, American School of Correspondence
Member, American Society of Mechanical Engineers

**F. HALLETT LOVELL, JR.**

President and Treasurer, Lovell-McConnell Manufacturing Company

**W. R. HOWELL**

President, W. R. Howell and Company, London, England

**WILLIAM K. GIBBS, B. S.**

Associate Editor, *Motor Age*, Chicago

**JESSIE M. SHEPHERD, A. B.**

Head, Publication Department, American Technical Society

# Authorities Consulted

THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness, particularly, to the following eminent authorities, whose well-known treatises should be in the library of everyone interested in the Automobile and allied subjects.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

CHARLES E. DURYEA

Consulting Engineer
First Vice-President, American Motor League
Author of "Roadside Troubles"

OCTAVE CHANUTE

Late Consulting Engineer
Past President of the American Society of Civil Engineers
Author of "Artificial Flight," etc.

E. W. ROBERTS, M. E.

Member, American Society of Mechanical Engineers
Author of "Gas-Engine Handbook," "Gas Engines and Their Troubles," "The Automobile Pocket-Book," etc.

SANFORD A. MOSS, M. S., Ph. D.

Member, American Society of Mechanical Engineers
Engineer, General Electric Company
Author of "Elements of Gas Engine Design"

GARDNER D. HISCOX, M. E.

Author of "Horseless Vehicles, Automobiles, and Motorcycles," "Gas, Gasoline, and Oil Engines," "Mechanical Movements, Powers, and Devices," etc.

AUGUSTUS TREADWELL, JR., E. E.

Associate Member, American Institute of Electrical Engineers
Author of "The Storage Battery: A Practical Treatise on the Construction, Theory, and Use of Secondary Batteries"

**BENJAMIN R. TILLSON**

Director, H. J. Willard Company Automobile School
Author of "The Complete Automobile Instructor"

**THOMAS H. RUSSELL, M. E., LL. B.**

Editor, *The American Cyclopedia of the Automobile*
Author of "Motor Boats," "History of the Automobile," "Automobile Driving, Self-Taught," "Automobile Motors and Mechanism," "Ignition Timing and Valve Setting," etc.

**CHARLES EDWARD LUCKE, Ph. D.**

Mechanical Engineering Department, Columbia University
Author of "Gas Engine Design"

**P. M. HELDT**

Editor, *Horseless Age*
Author of "The Gasoline Automobile"

**H. DIEDERICHS, M. E.**

Professor of Experimental Engineering, Sibley College, Cornell University
Author of "Internal Combustion Engines"

**JOHN HENRY KNIGHT**

Author of "Light Motor Cars and Voiturettes," "Motor Repairing for Amateurs," etc.

**WM. ROBINSON, M. E.**

Professor of Mechanical and Electrical Engineering in University College, Nottingham
Author of "Gas and Petroleum Engines"

**W. POYNTER ADAMS**

Member, Institution of Automobile Engineers
Author of "Motor-Car Mechanisms and Management"

**ROLLA C. CARPENTER, M. M. E., LL. D.**

Professor of Experimental Engineering, Sibley College, Cornell University
Author of "Internal Combustion Engines"

**ROGER B. WHITMAN**

Technical Director, The New York School of Automobile Engineers
Author of "Motor-Car Principles"

**CHARLES P. ROOT**
Formerly Editor, *Motor Age*
Author of "Automobile Troubles, and How to Remedy Them"

**W. HILBERT**
Associate Member, Institute of Electrical Engineers
Author of "Electric Ignition for Motor Vehicles"

**SIR HIRAM MAXIM**
Member, American Society of Civil Engineers
British Association for the Advancement of Science
Chevalier Légion d'Honneur
Author of "Artificial and Natural Flight," etc.

**SIGMUND KRAUSZ**
Author of "Complete Automobile Record," "A B C of Motoring"

**JOHN GEDDES McINTOSH**
Lecturer on Manufacture and Application of Industrial Alcohol, at the Polytechnic Institute, London
Author of "Industrial Alcohol," etc.

**FREDERICK GROVER, A. M., Inst. C. E., M. I. Mech. E.**
Consulting Engineer
Author of "Modern Gas and Oil Engines"

**FRANCIS B. CROCKER, M. E., Ph. D.**
Head of Department of Electrical Engineering, Columbia University
Past President, American Institute of Electrical Engineers
Author of "Electric Lighting;" Joint Author of "Management of Electrical Machinery"

**A. HILDEBRANDT**
Captain and Instructor in the Prussian Aeronautic Corps
Author of "Airships Past and Present"

**T. HYLER WHITE**
Associate Member, Institute of Mechanical Engineers
Author of "Petrol Motors and Motor Cars"

**ROBERT H. THURSTON, C. E., Ph. B., A. M., LL. D.**
Director of Sibley College, Cornell University
Author of "Manual of the Steam Engine," "Manual of Steam Boilers," etc.

**MAX PEMBERTON**
Motoring Editor, *The London Sphere*
Author of "The Amateur Motorist"

**HERMAN W. L. MOEDEBECK**
Major and Battalions Kommandeur in Badischen Fussartillerie
Author of "Pocket-Book of Aeronautics"

**EDWARD F. MILLER**
Professor of Steam Engineering, Massachusetts Institute of Technology
Author of "Steam Boilers"

**ALBERT L. CLOUGH**
Author of "Operation, Care, and Repair of Automobiles"

**W. F. DURAND**
Author of "Motor Boats," etc.

**PAUL N. HASLUCK**
Editor, *Work* and *Building World*
Author of "Motorcycle Building"

**JAMES E. HOMANS, A. M.**
Author of "Self-Propelled Vehicles"

**R. R. MECREDY**
Editor, *The Encyclopedia of Motoring, Motor News*, etc.

**S. R. BOTTONE**
Author of "Ignition Devices," "Magnetos for Automobiles," etc.

**LAMAR LYNDON, B. E., M. E.**
Consulting Electrical Engineer
Associate Member, American Institute of Electrical Engineers
Author of "Storage Battery Engineering"

# Foreword

THE period of evolution of the automobile does not span many years but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages, has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced novice, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. Astonishing refinements in the ignition, starting, and lighting systems

have lately been effected, thus increasing the reliability of the electrical equipment of the automobile as well as adding greatly to the pleasure in running the car. This, coupled with the extension of the electrical control to the shifting of gears and other important functions, has made the electric current assume a position in connection with the gasoline automobile second only to the engine itself. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

¶Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place, but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the principal systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, and Garage Design and Equipment.

¶For purposes of ready reference and timely information so frequently needed in automobile operation and repair, it is believed that these volumes will be found to meet every requirement.

# Table of Contents

## VOLUME II



* For page numbers, see foot of pages.

† For professional standing of authors, see list of Authors and Collaborators at front of volume.

REAR VIEW OF JEFFERY "SIX" CHASSIS, SHOWING UNDERSLUNG REAR SPRING SUSPENSION

# GASOLINE AUTOMOBILES

## PART V

---

## STEERING GROUP

The mechanisms by which steering is effected are among the most important features of a car, if not actually the most important. The truth of this statement will be realized when attention is called to the fact that safe steering is the final requisite that has made the modern high speeds possible, for without safe and dependable steering gears, no racing driver would dare to run a machine at a high rate of speed, knowing that at any minute the unsafe steering apparatus might shift the control, thus allowing the front wheels to waver and the car to run into some obstruction by the roadside.

The same argument applies in an even greater degree to the case of the non-professional driver, who wants to be on the safe side even more, perhaps, than do the dare-devils who drive racing cars. Nearly all of our roads are curved and, to make all of these turns with safety, the steering gear must be reliable. Again, in mountainous country where there may be a sheer drop at the roadside of hundreds of feet, it becomes necessary that the steering mechanism be very accurate and that it obey, at once, the slightest move on the driver's part. To secure this accuracy, there must be no lost motion or wear of the interrelated parts.

These things mean that the whole steering mechanism must be safe and reliable; strong and accurate; well made and carefully fitted; well cared for; and finally, the design and construction must be based on a theoretically correct principle, for otherwise the mechanical refinements will have been wasted. Perhaps it will be more logical to treat the mechanical requirements first by showing how the present type has been evolved from the failures of earlier forms.

### STEERING GEARS

**General Requirements.** In turning a corner a car follows a curve, the outer wheels obviously following curves of longer radius than do the inner wheels and, therefore, traveling farther. In

straight-ahead running, the wheels run parallel at all times and travel the same distance. These two facts are the basic ones which make the steering action so complicated: First, that on straight-ahead running the wheels must travel the same distance; and second, that on turning curves the outer wheels, whichever they may be, must travel a greater distance.

This double requirement leads to the usual form of steering arrangement, called after its inventor, the "Ackerman". It was Ackerman who brought out the first vehicle in which the front wheels were mounted upon pivoted-axle ends, these ends being pivoted on the extremities of the central part of a fixed axle, while the pivoted ends carried one lever each. These levers were connected together by means of a cross-rod, while at one end another rod was attached, which was used to move the wheels. By moving this latter rod, both wheels were compelled to turn about their pivot points, since the cross-rod joined them together, and if one moved the other had to move also. This was Ackerman's substitute for the fifth wheel which had been used up to that time and is even today on all horse-drawn vehicles.

**Inclining Axle Pivots.** The situation is further complicated by the fact that the ideal arrangement, that is, the fixing of the steering pivot at the center of the turning wheel in order to allow the maximum turning movement for the minimum motion of the hand, is not suitable for general use. In practice, however, it is placed as close to the ideal position as possible, which, in the ordinary case, is within three to six inches.

This approximation to the ideal has been made by inclining the stud-axle pivot inward, so that its center line prolonged would strike the ground at a point coincident with the center line of the tire. This same result is also brought about by inclining the stud axle itself downward. The construction gives added safety, in that the force of head-on collisions is supposed to be delivered at or near the line of incidence.

The axle-spindle center may be brought close to the wheel hub by means of a double yoke, but this was tried and abandoned as too cumbersome for the results effected. A method of placing the steering pivot in the center of the wheel was also developed. In this case the pivot was enclosed in a hollow hub; but as this made the

pivot, which is liable to wear, inaccessible, it also was abandoned. However, later tendencies point toward a revival of this construction.

The result is that today we are using a form which, though far from being ideal, fulfills every practical requirement. This form is usually constructed as in Fig. 316, which shows a skeleton plan view of an automobile. In this, the line $AB$ represents in length, position, and direction, the front axle of a car, while $ML$ represents in a similar manner the rear axle. $A$ and $B$ also are the pivot points for the axle-stud ends or, as they are more commonly called, the

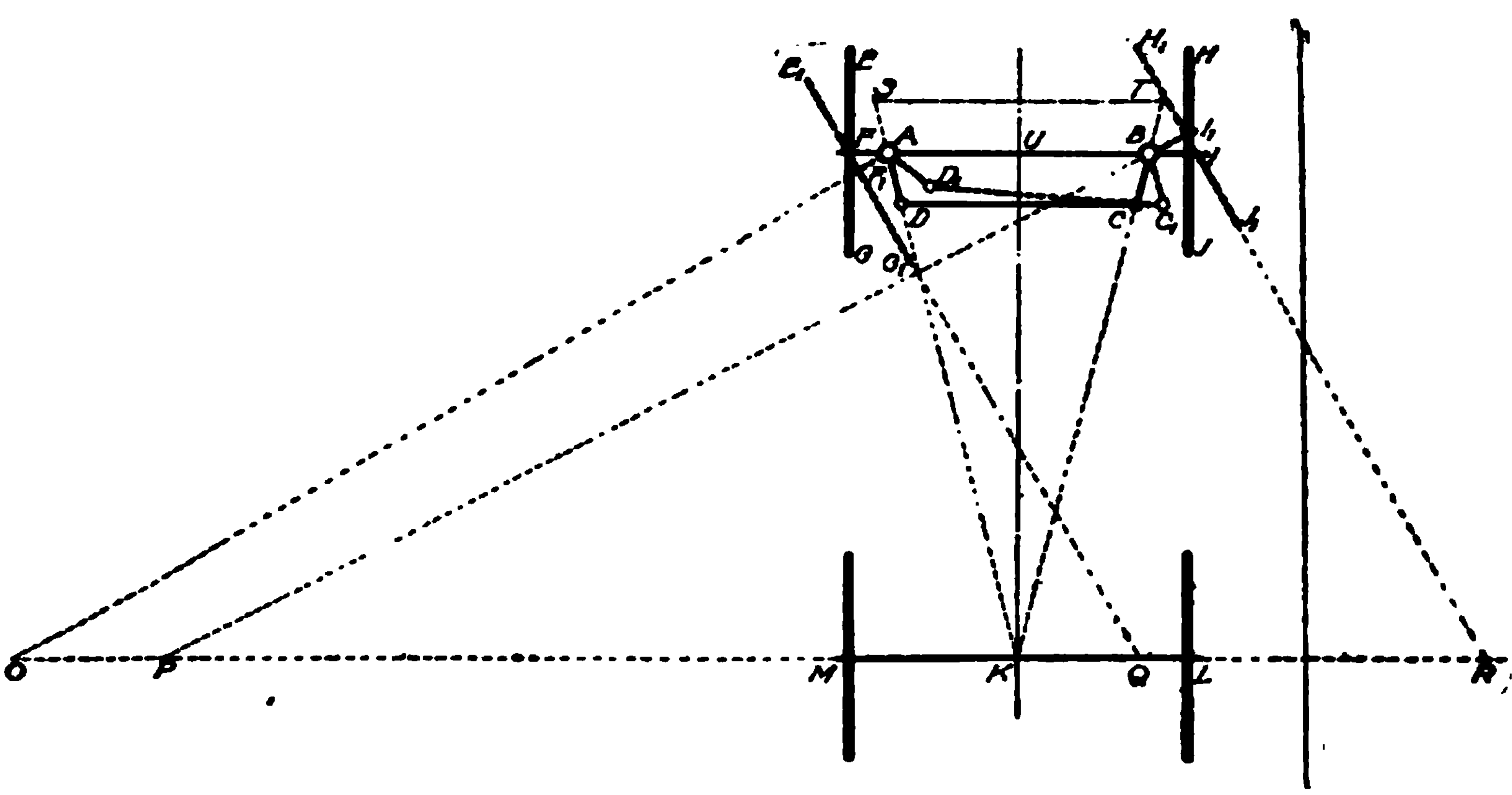


Fig. 316. Diagram of Steering Connections

steering knuckles or steering pivots, which are represented by the lines $AD$ and $BC$.

The rear (or front, as the case may be) ends of the steering knuckles are joined by the connecting rod $DC$. The Ackerman construction is such that the center lines of the steering arms, or levers, $AD$ and $BC$, prolonged, must pass through the center point of the rear axle at $K$; the reason for this is that the front wheels are supposed to turn about the center of the rear axle as a center.

**Action of Wheels in Turning.** If the wheels are supposed to turn through an angle, the action of the above arrangement will be seen. Suppose the steering gear (not shown in Fig. 316) is turned so as to move the steering lever $AD$ to the new position, shown dotted at $AD_1$. This movement will also move the other lever $BC$ to a new position, shown dotted at $BC_1$. It will be noted in this position that the angle through which the right-hand lever $BC$ has swung is not as

great as that through which the left-hand lever $AD$ has moved, although the two levers are attached together by means of the cross-connection $DC$.

The wheels are mounted upon the extremities of the steering knuckles at $F$ and $I$; $EG$ represents the left wheel, and $HJ$ the right wheel. These turn about the pivot points $A$ and $B$, with the movement of the steering knuckles to the new positions, shown dotted at $E_1F_1G_1$ and $H_1I_1J_1$. In this position, prolongations of the lines through the pivot point and the center of the two wheels will meet the rear-axle center line prolonged at separate points as $OP$, the two lines converging slightly. This same convergence may be noted by prolonging the center line of the two wheels $E_1G_1$ to $Q$ and $H_1J_1$ to $R$. This divergence means that the two wheels are turning on curves of different radii, and since the outer wheel $H_1J_1$ shows a longer distance from its center line prolonged to the rear-axle line $OPMKL$ than does the inner wheel, that is, has the longer false radius, $PI_1$ being longer than $OF_1$, it follows that the turning action will be correct.

This is somewhat complicated and rather hard to follow, but the figure seems simple and should be examined closely, even drawing it out step by step, as outlined above, for the purpose of making the steering action clear. Laying this out for one's self will bring out the reason why the steering knuckles do not move through the same distance and thus bring about a different movement of the wheels.

**Steering Levers in Front of Axle.** That the final movement of the wheels will not be changed if the levers, Fig. 316, are laid out in the same way but in front of the axle will be evident by prolonging the levers to $S$ and $T$, respectively, making the lengths $AS$ and $BT$ the same as the former lengths $AD$ and $BC$. Connecting the two by the rod $ST$ completes the front arrangement, which is seen to give the same results as the other. The choice of a front or rear location depends upon certain things, such as the safety of the cross-rod, etc., which will be brought out later on. Some machine manufacturers even go so far as to fit both front and rear levers to the same machine.

While shifting the lever from rear to front in Fig. 316 does not change the result at all, in Fig. 317 it does. In this construction,

known as the Davis, the steering levers are set in front, but taper inward instead of outward, so that their center lines prolonged meet the center line of the car prolonged at a distance from the front axle equal to the distance between the front and rear axles, or equal to the wheel base.

In addition, the connecting rod is carried in guides placed on the front of the axle, so that its path of travel is always parallel to the front axle. Consequently, the levers must be made slotted or telescopic. The result of this combination of movements is an

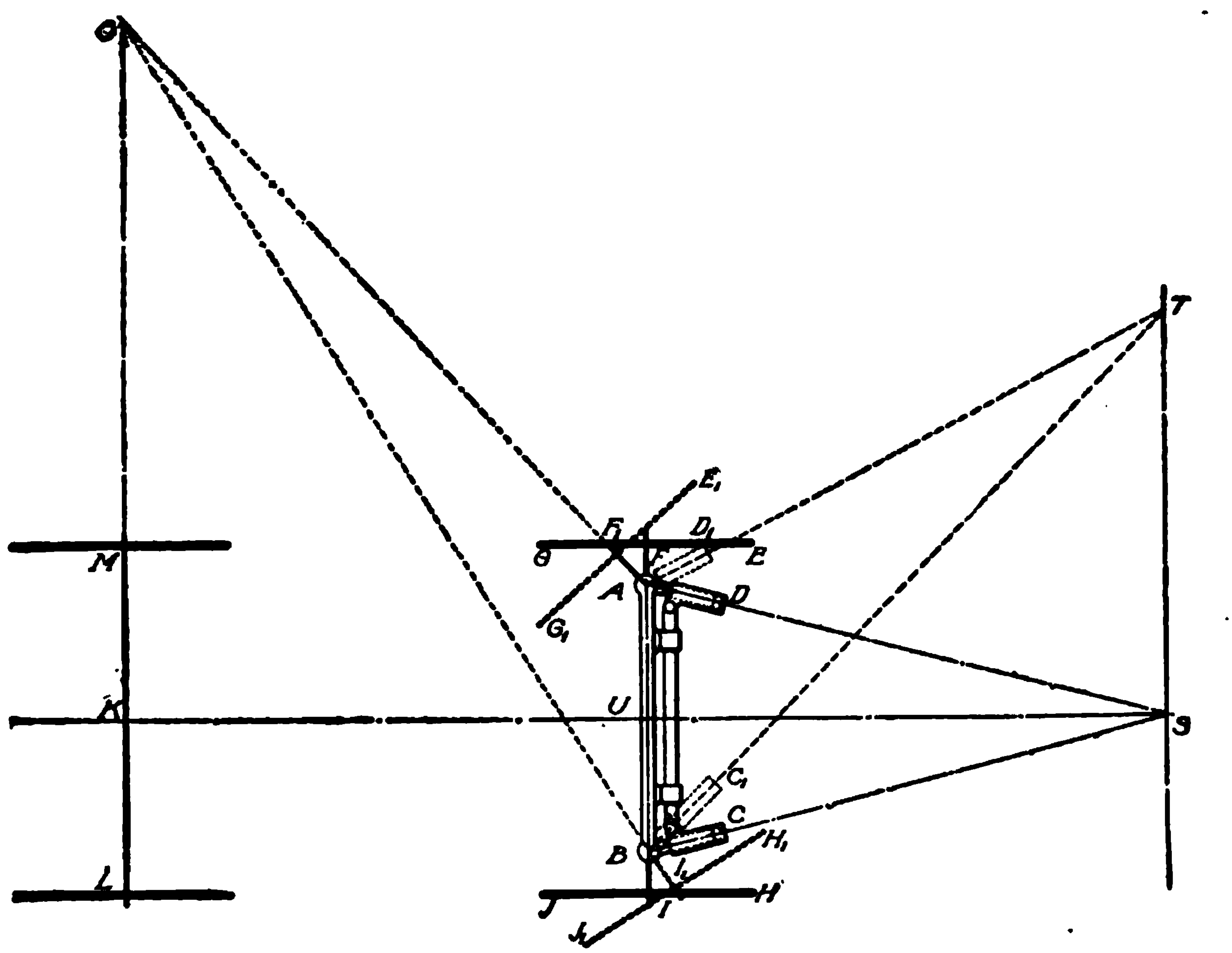


Fig. 317. Patented English Steering Device, Said to be Theoretically Perfect

absolutely correct angle to both wheels for any angle of lock. This can be explained by a reference to the diagram.

In Fig. 316 the prolongations of the wheel center lines, or radii of turning, do not strike the center line of the rear axle—about which they are supposed to turn—at a common point, the difference being the amount they are out of true, viz, the distance between the points *O* and *P*. If Fig. 317 be lettered to correspond with Fig. 316, the prolongations of the knuckle center lines $AF_1O$ and $I_1BP$ in Fig. 316 become the two converging lines $AF_1O$ and $I_1BO$ meeting

at the point $O$ on the center line $LMO$ of the rear axle prolonged. This is as it should be and shows the case of correct steering and turning.

In this case, all four wheels are turning about the point $O$, the two rear wheels with the radii $OM$ and $OL$, and the two front wheels with the radii $OF_1$ and $OI_1$, respectively. This gives a theoretically correct case in which all wheels will round any curve as they should and not slip or slide around, damaging the tires in the process. The Davis type of steering gear, it may be remarked, is not in general use, its construction adding a number of parts to the more usual form, shown in Fig. 316, which gives close enough results for average use.

Like the sliding-gear transmission, a steering gear is a form of mechanism which, although used on nearly all automobiles, is, from a theoretical and mechanical standpoint, far from what it should be.

**General Characteristics of Steering Gears.** *Standard Types.* The movement or deflection of the front road wheels is obtained by

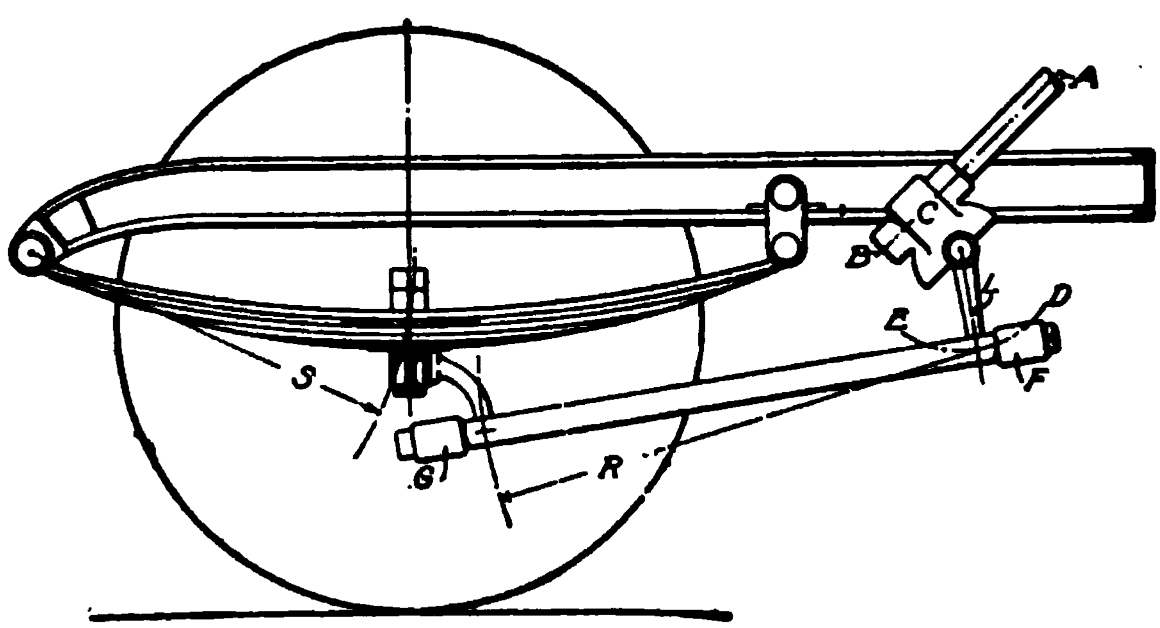



Fig. 318. Typical Steering Gear and Connections to Front Axle

a crosswise movement of the tie rod which links the steering-knuckle levers attached to the wheels. This tie rod, sometimes referred to as the cross-connecting rod, is actuated by the drag link $GF$, Fig. 318, which is pivotally mounted on the steering-knuckle lever $L$. The drag link has a linear movement along the frame and is parallel with it.

The drag link is also pivotally mounted at the ball arm of the steering gear $C$, and when the drag link is moved forward or backward by movement of the ball arm, the tie rod is moved at right angles, deflecting the wheels. The drag link has a semi-rotary motion; that is, its upper end is turned through a part of a revolution while its lower end, to which the drag link is attached, swings

through a fairly large arc, according to the capacity and design of the steering gear.

As the ball arm swings through its arc, the drag link attached to it rises and falls slightly, the movement being indicated by the dotted lines in Fig. 318. The partial circular motion in a vertical plane is converted from the rotation of the steering gear in a horizontal plane by several methods. The gear shown in Fig. 319 is known as the worm and sector type, which is illustrated in Fig. 318.

In Fig. 319 the steering column or post *CD* carries a worm *F* which is in mesh with the gear *E*. Rotating the column *CD* in the direction indicated by the arrows, or counter-clockwise, will result in the worm turning in the same direction. The gear *E* will rotate on its horizontal shaft in a downward movement, as shown by the arrow, and as the ball arm, or lever, is attached to the shaft, the member *L* will move backward, or to the left, as shown by the arrow intersecting the ball. With the worm type the two gears are usually in two different planes at right angles to each other, one vertical and the other horizontal. This is an advantage in that it lends itself readily to the construction of a simple steering-gear system. Thus the post is in a vertical or modified vertical line, as is also the motion of the steering arm, and the consequent movement of the steering rod is more or less confined to a vertical plane. With the worm and gear this is obtained in a simple manner. The gearshaft is in a horizontal plane passing through the center line of the worm. If the worm rotates in a direction which approximates a horizontal circle around a vertical axis, the worm gear will turn in a vertical plane about a horizontal axis. A lever attached to the end of this shaft will, consequently, move in the desired

Fig. 319. Worm and Partial Gear of Typical Steering Gear

plane—the vertical one mentioned before—and the desired requirements are met.

The conversion of rotary motion in a horizontal plane to partial rotation in a vertical plane is shown in Fig. 320, the action here being slightly amplified. The steering, or hand, wheel $A$ with spokes $B$ is turned to the left, turning the steering column $C$ (a hollow tube) in the direction indicated by the small arrow. $D$ is the steering gear with its ball arm $E$. The turning of the hand wheel moves the ball end $F$ and drag link backward. The front end of the drag link is attached to the steering knuckle $M$ at $H$ and turns about the center line $KL$ of the steering knuckle $J$, the end turning through

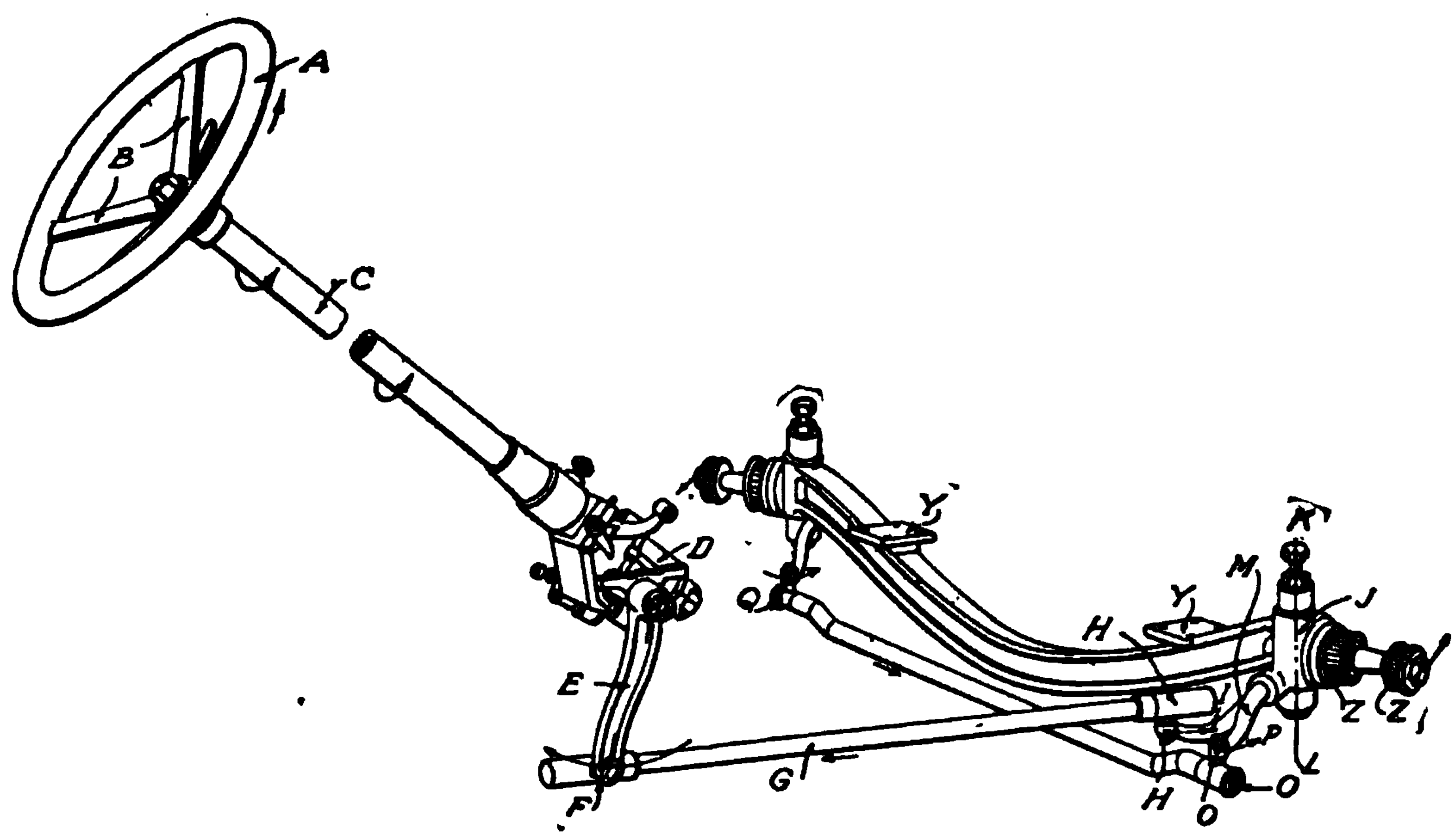



**Fig. 320. Steering Mechanism and Front Axle of Pierce-Arrow Car**
*Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York*

the arc $HI$. The lever $M$ is attached to the knuckle $J$ and turns with it. Its end turns through the arc $OP$, moving the tie rod $OQ$ to the right and turning the other knuckle in the same way and direction. $YY$ are the spring pads and $ZZ$ the tapered roller bearings supporting the road wheels.

*Classification.* There are three general forms of steering gears: the worm, the bevel, and the spur. These may be subdivided, which might lead one to assume that there are a dozen or more different forms. The mechanical lever has been discarded because of its tendency to impart all road shocks to the driver; it is fully reversible at all times. Irreversibility is employed because it transmits to

the road wheels any turning movement imparted by the driver without reversing or carrying back to the operator the original movement of the road wheels.

Many attempts have been made to substitute another form of mechanism for steering gears; this consists of various rod, lever, chain, and spring combinations. All of these have failed, however, because they lacked the fundamental requisite of irreversibility.

Aside from the many schemes mentioned which seek to avoid the use of the regular gear in the standard manner, there have been a number of unsuccessful attempts to avoid its use in other ways. Fig. 321 shows some of the gears which have been tried. At *1* is seen a device in which the rotation of a large bevel gear turned a small bevel pinion, the rotation of the latter serving to screw a long straight lever with a threaded inner end into or out of the interior of the threaded bevel pinion.

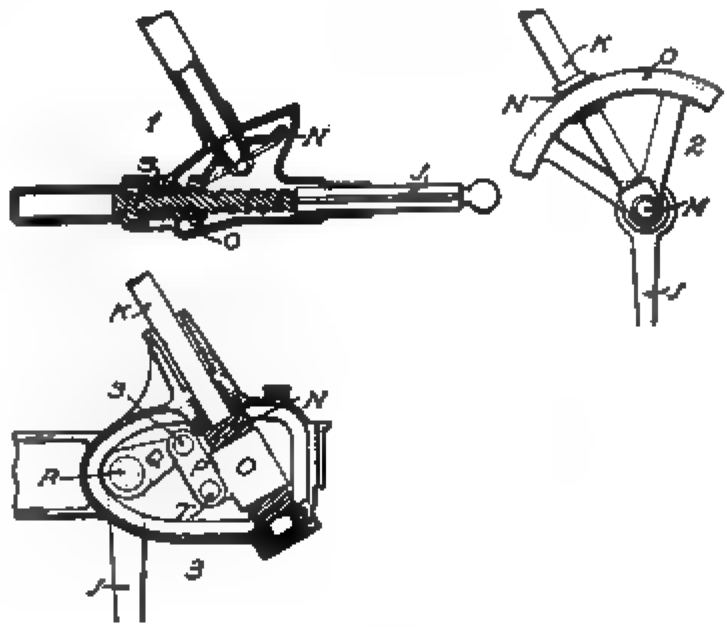


Fig. 321. Obsolete Forms of Worm Steering Gears

In the figure, $N$ is the actuating bevel turned by the movement of the operator's hands, while $O$ is the smaller actuated bevel pinion. Within this is seen the worm end $S$ of the lever $J$, the ball at the outer end being connected to the steering knuckle. Since the bevel alone lost a great deal of power in friction, while the worm arrangement and the sliding action of the lever in its bearings did likewise, the total effort to turn this must have been enormous. At *2* is shown another form, which is the double-bevel

arrangement; a small bevel *N* attached to the steering post *K* turns the larger bevel *O*, which is pivoted at the axis *M* about which the lever *J* attached to the segmental bevel *O* turns.

A most peculiar arrangement is shown at *3*, this being a combination of a worm and nut, two levers and a steering arm, as well as a connecting link for the two levers. Turning the hand wheel turns the worm, which moves the nut up or down. Since the nut is connected by means of the link to the lever, the motion of the nut up and down is transmitted to the short lever; this, in turn, moves the long-arm, or steering, lever. In the figure, *K* is the steering post, *N* the worm, *O* the nut, *P* the connecting link pivoted at the two ends *T* and *S*, *Q* the short-arm lever, and *J* the steering lever, the two latter being integral and pivoted at the point *R*. At *4* is shown a combination of a double internal worm with a rack and gear. In this, the turning movement of the inner worm causes the outer worm to travel up and down. Upon the exterior of this outer worm is cut a rack which is meshed with the gear, its up and down movements turning the gear around and thus effecting the steering, the steering lever being attached to the gear. *N* is the internal worm, *O* the external worm with the exterior rack, *P* the gear which meshes with it and carries the lever *J* as a part of it. At *5* is shown a combination of a double worm with a double ball and socket arrangement. The turning of the outer worm $N_1$ causes the inner worm *N* to rise and fall, the lower end of this carrying a ball-and-socket joint *O*, the end of the ball being formed integral with the steering lever *J*, which also has a ball and socket attachment at the other end. At *6* is shown a steering gear which was tried and discarded, but which is now coming to the fore and bids fair to oust many other forms of gear. It is variously called a globular worm, helicoidal worm, or Hindley worm, the worm forming a curve closely approximating the curve of the gear with which it is to mesh. This gives a greater number of teeth in mesh at any one time, spreading the wear over a larger surface and thus lengthening the life as well as accuracy of the steering gear.

**Spur and Bevel Types.** The spur- and bevel-toothed construction of gears may be reversible, and these types are to be found on low-priced cars, as the cost of cutting the gears is small. The spur gears have straight teeth, the edges, or sides, of the teeth being straight

and parallel with the axis of the shaft on which the gear turns. In bevel gears the teeth taper toward a point and are inclined to the axis of the shaft. Another construction is the spiral gear. Both types may be made reversible and irreversible as desired.

**Worm-Gear Types.** With a very few exceptions, automobile engineers favor the worm type of steering gear, and it will be found on the highest priced cars. It has the advantage of being irreversible and is utilized in several forms. In the worm class of gears, some types are closely related, while others vary widely. For example, the complete sector and gear type differ only in that the wheel operated by the worm makes a complete circle or part of a circle. The full gear can be turned through 90 degrees and replaced on the shaft without presenting a new surface to the worm. Some hold that the worm must be subject to some wear, especially where it is most used. They contend that turning over the pinion brings new teeth to engage with the worm and that these teeth will not mesh properly when turned at an angle of from 20 to 30 degrees.

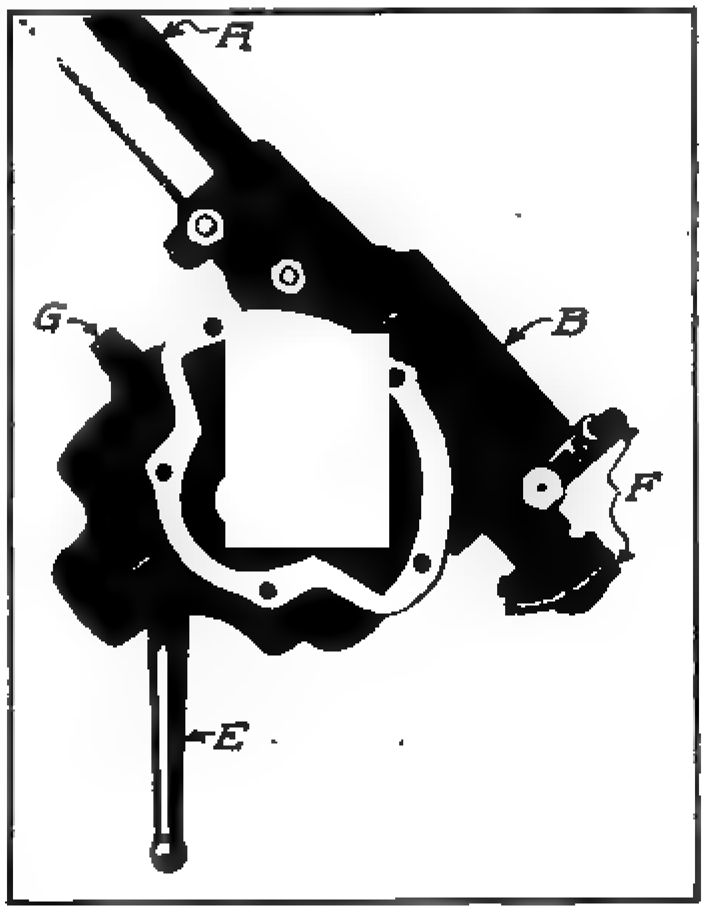


Fig. 322. Worm and Partial Gear Type of Steering Gear

*Worm and Partial Gear.* Fig. 322 illustrates a gear of the worm and partial gear type. Advantages claimed for the design are durability, ease of action, and adjustability to wear. The parts are accurately cut and hardened, and the worm is provided with a ball thrust on either side. With this type, the teeth, which are in the middle of the sector and in mesh, perform the greatest work when the car is driven in a straight line and are most susceptible to wear. To compensate for this wear, the center teeth are cut on a slightly less pitch radius so that lost motion may be eliminated without affecting the upper

and lower teeth of the sector and to prevent binding when turning at right angles. In the illustration, *A* is the steering column to which the worm *C* is secured, *D* is the sector in mesh with the worm, *E* is the ball arm, or lever, *B* the gear housing, *F* the spark and throttle bevel gears and levers, and *G* the lubricant plug.

Adjustment. Two principal adjustments are provided. End play of the worm is eliminated by loosening the jamb nuts and lock screws on the column housing. Displacing the oil plug *G* will disclose an adjusting collar which is set with a screwdriver. Adjust collar until all play is eliminated, but the worm must turn easily. The lock screws, above referred to, are so located in the gear housing that when one is directly over a slot in the adjusting collar the other is between two slots. Consequently, after adjusting the collar it is essential that the proper screw be selected for locking the adjustment. Both locking members must be prevented from turning, by using the nuts. Wear of the teeth of the worm and sector may be eliminated by means of an eccentric bushing, which, when turned, moves the sector into a closer relation with the worm. This is accomplished by removing a locking screw at the left of the ball arm and moving the arm, which turns the eccentric bushing. In case of extreme wear, it may be necessary to displace the ball arm and set the locking-screw section in a different position on the end of the hexagonal end of the eccentric bushing so as to bring the arm in such a position that it can be locked by the screw. End play of the sector shaft is eliminated by removing a locking arm and turning an adjusting screw in, after which the arm and lock screw are replaced and both set up tight.

*Worm and Full Gear.* A full gear and worm type of steering gear is shown in Fig. 323, with the gear cover removed. This type is irreversible, and the advantage claimed for it is that it can be easily removed and so readjusted that an unworn section of the gear may be brought into contact with the worm. This is a simple form, and it is possible to replace a worn gear with a new one, as the gears are not expensive.

Fig. 324 shows a much more complicated form of worm and full gear in which the inventor has attempted to gain something by the use of a double steering gear, that is, two complete sets of worms and gears set opposing one another, the gears being made to mesh with each other just like a pair of spur gears. Since the lever can

be attached to but one of the turning gears, the other gear with its actuating worm is useless. The inventor doubtless intended the two worms to oppose each other and thus be self-sustaining as to thrust, but such would not be the case, the actual thrust being in opposite directions in the two cases of the upper and lower worms, the total thus being double the usual amount.

Adjustment. The part most subject to wear is that section of the gear which meshes with the worm when the front wheels are traveling in approximately a straight line. Because of this wear, the teeth of the wheel are subject to deterioration. Usually the adjust-

Fig. 323. Typical Worm and Full Gear Steering Device

ment for the wear is made by bringing the worm into a closer relationship with the gear by using the eccentric bushings which support the worm shaft. This adjustment is practical when the lost motion is due to poor adjustment rather than to wear of the teeth. With the majority of types, it is possible to displace the steering arms, move the steering wheel about half a turn, then replace the worm wheel so that an unworn section opposite the worn teeth will be brought into engagement with a comparatively unworn portion of the worm proper. The eccentric bushings in this case can be utilized to obtain a correct meshing of the worm and gear teeth. End play of the worm

can be removed by adjusting the ball thrust bearings on either side of the worm. Sometimes these bearings become dry, or the lubricant becomes gummy, causing the shaft to turn hard. Wear of plain bushings in the steering-gear case is responsible for lost motion; the remedy is to replace the bushings with new members.

*Worm and Nut.* Next to the worm and gear, either full or partial, the form of steering gear most used is the worm and nut. which is made in several different combinations. Thus, the nut may operate the steering lever directly through the medium of a secondary lever, or it may actuate a block, which, in turn, moves either the lever direct or the secondary lever. In Fig. 325 another form of

Fig. 324. Double Worm and Gear Steering Device

Fig. 325. Worm and Nut Steering Device

the worm and nut variety is shown. This has a nut which the turning of the worm moves up and down but which is split, the two halves being bolted together. A spherical seat is formed in the two halves of the split nut into which a ball-end lever is set, the bolt serving to clamp the two pieces together and hold the lever there.

This is the end of the secondary lever, which is connected by means of another lever to the steering lever itself. In the figure, $A$ is the worm, $B$ and $B_1$ the two parts of the nut, $C$ the clamping bolt, and $D$ the hinge at the other end. $E$ and $E_1$ represent the spherical seats for the ball end of the other lever.

Having the nut in two widely separated parts reduces the wear on each, since the bearing surface is spread out more than would be


Fig. 326. Steering Gear Used on Heavy Manhattan Trucks

the case with an uncut nut. In addition, the split nut allows the changing of the ball-end lever at any and all times.

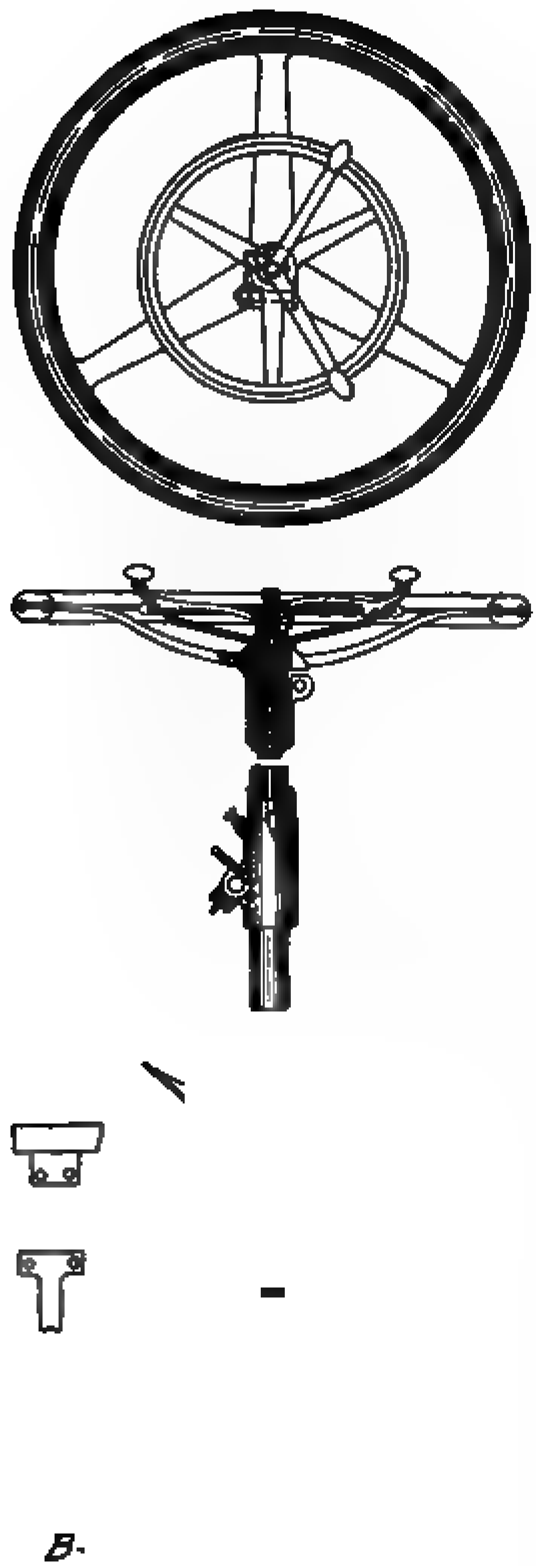



Fig. 327. Sectional Details of Steering Gear of Winton Cars
*Winton Motor Car Company, Cleveland, Ohio*

In Fig. 326 is shown a form of worm and nut steering gear which is used on very heavy trucks and commerical cars. In this gear, the double worm is used; the inner worm carries, at its lower end, a block which is pivoted in a combination lever and shaft, to which the steering arm is attached. In the figure, *A* is the hand wheel turning the rod *B* within the steering-post tube *C*. This rod is driven into and keyed at its lower end to a member *D* which has internal worm threads. Another member *E* has a circular upper end on which are worm threads, while its lower end is slotted. The worm at the upper end meshes with the internal worm threads in piece *D*, while the lower slotted end carries, between the two arms of the slot, a rectangular block *F*. This block is hardened and ground all over and is fastened to the forked end of piece *E* by means of the hardened and ground pin *G*. This pin also passes through the arm *H* of the shaft to which the steering arm is attached. The steering arm is free to rotate about the center. This rotation moves the steering lever *L* in the arm of a circle.

The steering action is as follows: Turning the hand wheel turns the outer worm. This worm cannot move, so the inner worm is forced to move up or down, as the case may be, and moves the block with the pin through it, which, being fixed in the arm

extension of the shaft, must turn the shaft. To this arm is attached the steering lever, so the latter must move. Although a rather complicated gear to explain and also to make, this gear, when finished, is an excellent one, and has been used for five or six years on heavy trucks with excellent results.

The Winton steering gear, Fig. 327, is not decidedly different from the one just shown, as will be noted by a close inspection of the parts. *A* is the internal worm, which is turned by the hand wheel, while engaging this worm are the block *B* and pin *C*, the block being partly cut away to show the engaging gear teeth. This block moves the jaw arm of the steering lever *D*. This jaw is not complete in this gear, but is cut away to save weight. The jaw arm, too, is connected directly with the steering lever, the jaw, arm, and shaft making one piece. The light work to which this was put made possible the economy in the number of pieces and in the weight of each. As before, turning the hand wheel turns the worm, which, in turn, moves the block and pin up and down and thus moves the jaw arm, which moves the steering lever.

Adjustment. The adjustment for lost motion in the worm and split-nut type of gear is generally made by loosening a cap screw on the column and screwing down an adjusting nut which has a right-hand thread. This adjusting nut acts directly on the thrust bearing, forcing the screw and half nuts, which slide, against the yoke rollers. In making the adjustment to a gear of this type, it is advisable to turn the road wheels to the extreme angle position, because the gear is the least worn at this point, and if it is adjusted only enough to take up the play when in this position, there will be danger of binding. Sometimes, when the adjustment is made with the road wheels straight, the gear will bind at the extreme positions.

*Worm and Worm.* In the worm and worm form of steering gear there is a worm within a worm, not wholly unlike the ones just described. Fig. 328 shows an example of this, which has a worm *C* attached to the steering rod *H*, which is turned by the steering wheel *A*. Within and without this are worm threads, an external worm *B* meshing with the internal worm on the inside of *C*, while an internal worm *D* meshes with the external worm on *C*. The action of turning the hand wheel, then, moves one of these upward and the other downward.

The lower end $B_1$ of the inner worm member presses against a hardened end of the steering-lever arm $E$, while the lower end $D_1$ of the outer worm member presses against the other hardened end $E_1$ of the same piece. There is no lost motion, or play, in the gear; when the hand wheel is turned, one worm rises and the other falls, as just described; the piece $E$ will let one end rise and the other fall, as it is acted upon by the lower extremities of the two moving worms. This piece is pivoted at $F$ and carries at its outer end the steering lever $G$, which thus moves in the customary manner. Within the steering post are the spark and throttle tube and rod $I$ and $J$, which

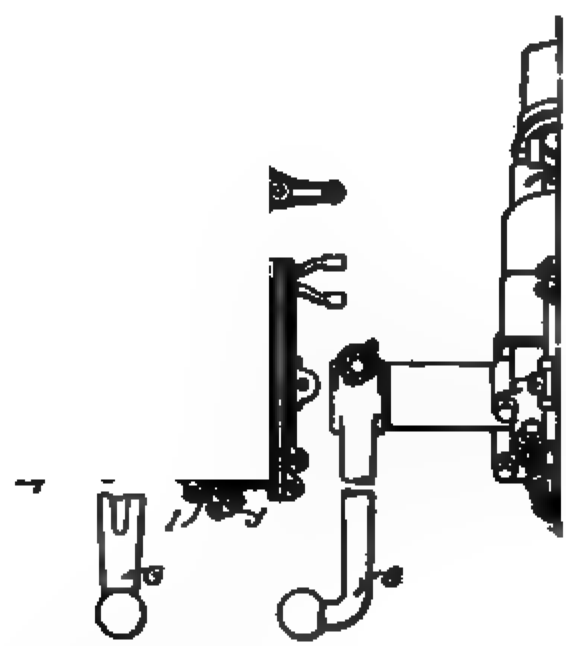


**Fig. 328. Section of Gemmer Steering Gear**
*Courtesy of Gemmer Gear Company, Detroit, Michigan*

carry right through the whole gear and out at the bottom, where the spark and throttle-actuating levers are attached.

Adjustment. The adjustment of the worm and worm type, an example of which is illustrated in Fig. 328, is generally effected by a nut located at the upper end of the gear housing. This nut is provided with flats to accommodate a wrench hold. The end of the worm-wheel shaft is squared, and to this square the steering-lever arms are attached by means of a pinch clamp and bolt.

*Bevel Pinion and Sector.* Among the other types of steering gears is that of the bevel pinion and sector, shown in Fig. 329. The

bevel pinion moves the bevel-gear sector back and forth as it is turned, this motion being transferred to the steering arm attached on the same shaft to which the bevel sector is secured. This type of gear is said to be effective, but it is not irreversible, and shocks to the road wheels may be imparted to the steering wheel and move it.

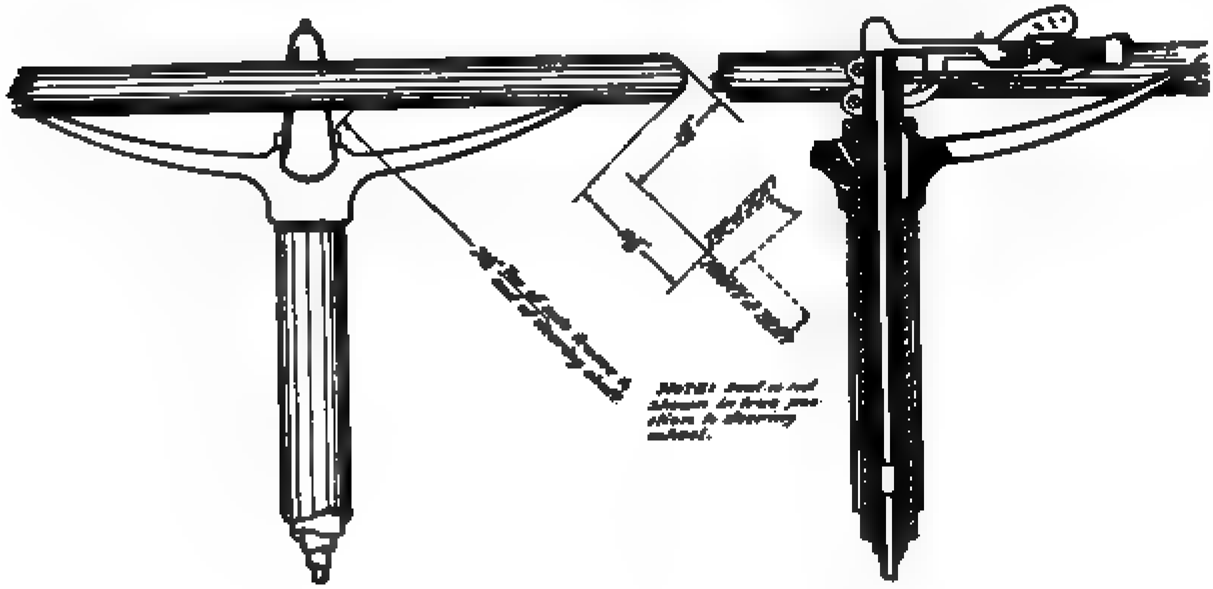


Fig. 329. Bevel Pinion and Sector Type of Steering Gear
*Courtesy of Reo Motor Car Company, Lansing, Michigan*

**Adjustment.** The bevel and sector gear has two adjustments. The pinion may be moved up or down, as required, by unlocking the clamp bolts (one of which is shown at *D*) which permits the moving of the entire steering column up or down so as to obtain the proper

relative position to the pinion and its sector. The position of the sector endwise may be adjusted by the block member $A$, which bears against a roller guide, forcing the sector into mesh more or less closely with the pinion. The spring $E$ is provided to prevent rattling, and the screw $H$ is a guide for the plunger and should not be disturbed in making the adjustment.

*Hindley Worm Gear.* There are a number of things about the Hindley type of worm which make it an excellent one to use for steering gears. A realization of this advantage is bringing about a greatly increased use of this form; so it will be appropriate and timely to look into its form, construction, and advantages.

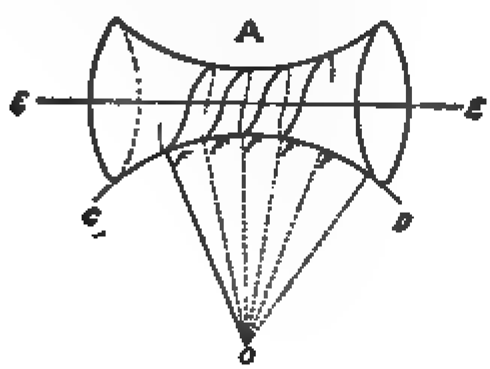



Fig. 330. Details of the Hindley Worm

The question of what makes the Hindley different from other worms naturally arises. The ordinary worm has the same diameter from one end to the other, the blank before the cutting of the teeth resembling a section of a cylinder. The Hindley, on the other hand, is not of uniform diameter, but has a smaller center diameter and enlarged ends. This gives it a waist, or hour-glass, shape.

An illustration will make this clear. Fig. 330 shows at $A$ how the Hindley shape is generated and at $B$ a finished gear, revealing plainly the reduced center diameter. In the upper figure, $EE$ is the center line, or axis, of the worm, and $O$ the center of the gear which is to mesh with it. $CD$ is a circular arc struck from $O$ as a center. If, on this curve $CD$, equal spaces be struck off, using a distance equal to the pitch of a single-threaded worm or the lead of a multiple-threaded one, as at $F$, and radial lines be drawn from the center $O$ to these points, these lines will be normal to the surface of the worm at those points; in short, the worm must pass through them, as roughly sketched in the figure. In the lower part $B$, of the figure, is illustrated a worm made on this principle, ready to be put into position.

This form of worm is used for the double reason of presenting more wearing surface—since it has at least three teeth in contact at any one time, as compared with one or at most two in the ordinary worm—and greater resistance to reversibility. The worm is used for steering gears because it is partly or wholly irreversible, its motion being a sliding one; nevertheless, all worms may be so cut as to be either wholly or not at all reversible. The sliding motion of the two parts in contact, as opposed to the rolling motion in the case of other mechanical movements of a similar nature, is greatly increased if there are three teeth in contact instead of the more usual one. If the friction of sliding be increased, the amount of reversibility will be decreased in the same proportion, for the added sliding friction will increase the natural reluctance of the worm to transmit power backwards. So much is this the case that it pays to use the Hindley form, despite its greatly increased cost of cutting.

**Ford Steering Gear.** The steering mechanism of the Ford car—a patented construction—differs radically from the conventional types in that its hand wheel does not directly rotate, or turn, the steering column or rod, but it imparts the necessary turning movement through the gearing and the use of a small shaft to which the hand wheel is attached. A phantom view of the gearing is shown in Fig. 331.

The steering column with its short shaft and drive pinion is enclosed in a tube or housing which is set at an angle and bolted to the dash. The housing does not extend the entire length of the column, as the lower end of it is mounted in a bracket that is rigidly bolted to the frame. The steering-gear post, or column, has a triangular flange at right angles to the rod, and each point of the flange has an integral stub, or pin, carrying a small spur pinion. The center of the rod is drilled and bushed to take a small shaft to which a fourth pinion, or drive pinion, is keyed. The upper part of the housing is shaped so as to provide a gear case, and the inner periphery of this case is cut to obtain spur teeth or, in other words, an internal ring gear. This gear is stationary.

The hand wheel is attached to the short shaft, and its drive pinion is held in place by a brass cover of the internal gear case. As the drive pinion of the shaft is in mesh with the three pinions mounted on the stubs of the steering column proper, and these three pinions are in mesh with the internal ring gear, any movement of the hand

wheel will rotate the drive pinion on its shaft. This movement will cause the three spur pinions to rotate in an opposite direction against the internal gear, thus reducing the movement of the steering column as compared to that of the hand wheel. The three spur pinions compensate for any pressure of the drag link and the tie rod.

The operation of the Ford steering-gear mechanism explains the basic principle of the operation of the hand wheel; that is why the wheel is turned in the same direction that the driver desires the car to

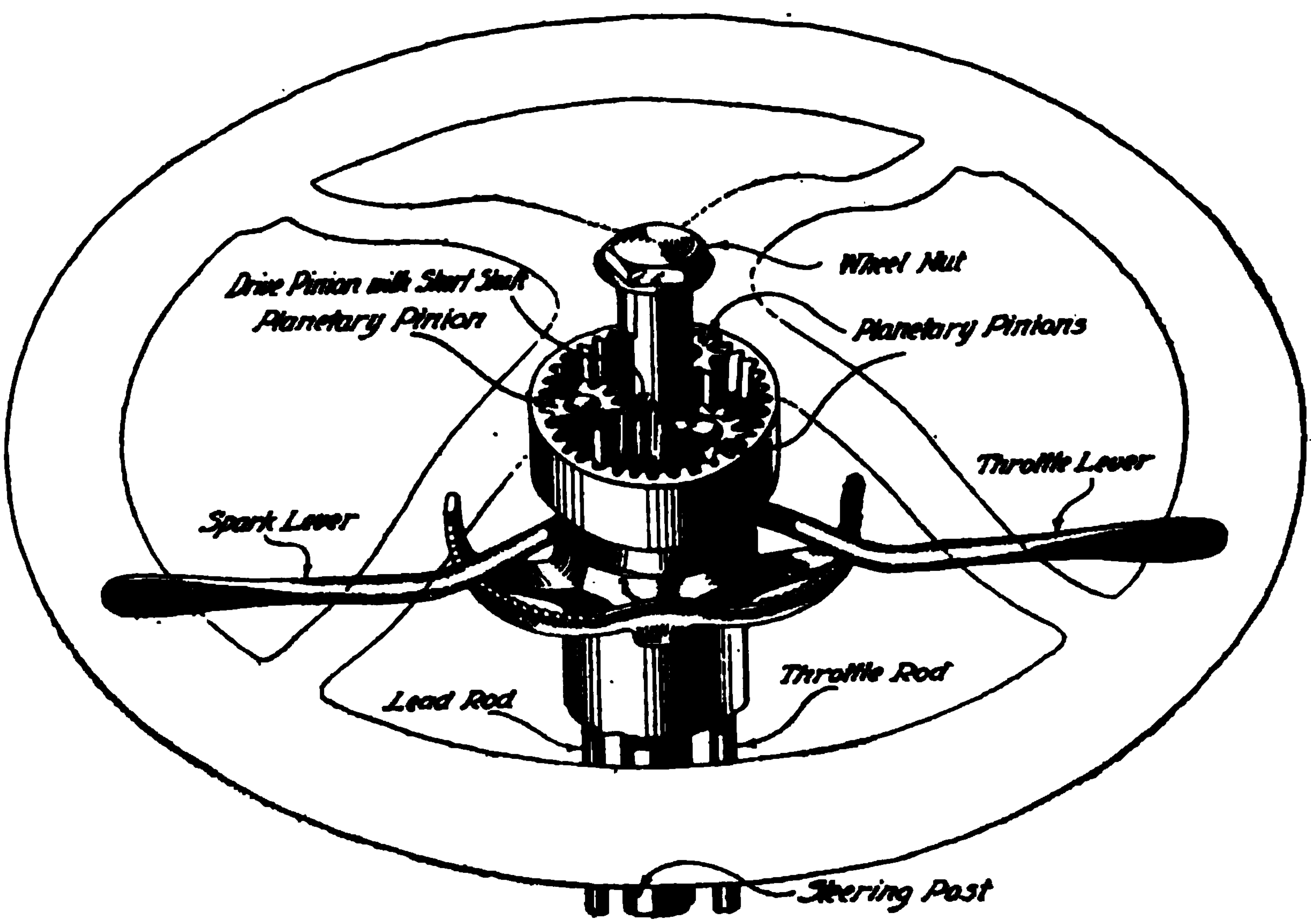



Fig. 331. Ford Planetary Steering Gear—An Unconventional Type

go. If the hand wheel is revolved from left to right, for example, the movement causes the three pinions mounted on the pins of the steering column to rotate from right to left; the pinions rotating against the stationary internal gear turn the steering rod in the same direction taken by the three pinions. The column swings an arm attached to it from right to left, and, as the rod is secured to this arm, it moves in the same direction, swinging the front road wheels so that they move from left to right, and to a degree that will correspond with the turning, or movement, of the hand wheel. It should be understood that the movement from left to right refers to the front half of the road wheels. If the driver desires to direct the vehicle to the left, the wheel is turned to the left.

The drag link of the Ford steering gear differs from conventional designs in that it is at right angles to the frame and is practically two-thirds the length of the tie rod. The end of the steering column is provided with an arm carrying a ball, and the drag link, or steering-gear connecting rod, as it is listed by Ford, has a ball-socket cap which fits over the ball of the steering rod. The drag link also has a ball socket at its other end, which fits over a ball arm on the tie rod. The tie rod, called the spindle connecting rod because it connects the spindles, is provided with yokes at either end, and these yokes are pivotally connected to the spindles by a bolt passing through them and through an eye in the spindle. The Ford drag link differs from others in usual practice in that it moves to the right and left, while those used on other cars move forward and backward. No provision is made with the Ford drag link for absorbing shocks or for automatically compensating for wear as usually is the case with the conventional type of drag link.

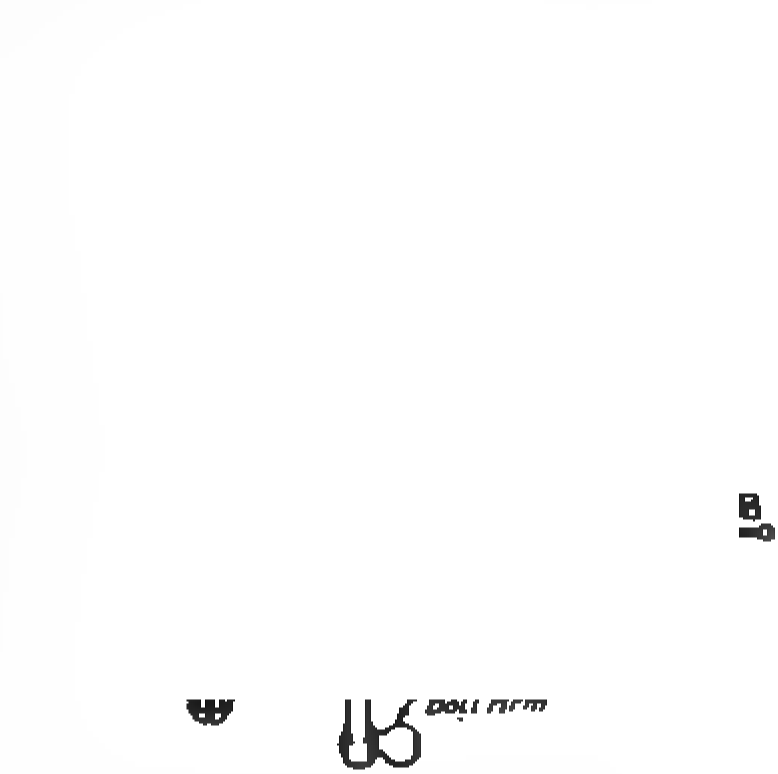


Fig. 332. Screw and Nut Gear Used on Trucks

**Semi-Reversible Gear.** The steering gear used on commercial cars, particularly trucks ranging from 3- to 7-ton capacity, must not only be capable of operation with a minimum effort, but it must absorb a great many of the minor shocks and a per cent of the larger shocks. The semi-irreversible type is most favored because of the above-named reasons. The design shown in Fig. 332 is of the screw and nut type. The nut is a solid piece, completely enveloping the screw, and the threads of the screw are in constant and complete engagement with the threads in the nut. The screw has a rotary motion and the nut has a longitudinal motion. The means of transmitting this longitudinal motion of the nut to the rotary motion of the steering arm is by circular discs at the lower end of the nut.

wheel will rotate the drive pinion on its shaft. This movement will cause the three spur pinions to rotate in an opposite direction against the internal gear, thus reducing the movement of the steering column as compared to that of the hand wheel. The three spur pinions compensate for any pressure of the drag link and the tie rod.

The operation of the Ford steering-gear mechanism explains the basic principle of the operation of the hand wheel; that is why the wheel is turned in the same direction that the driver desires the car to

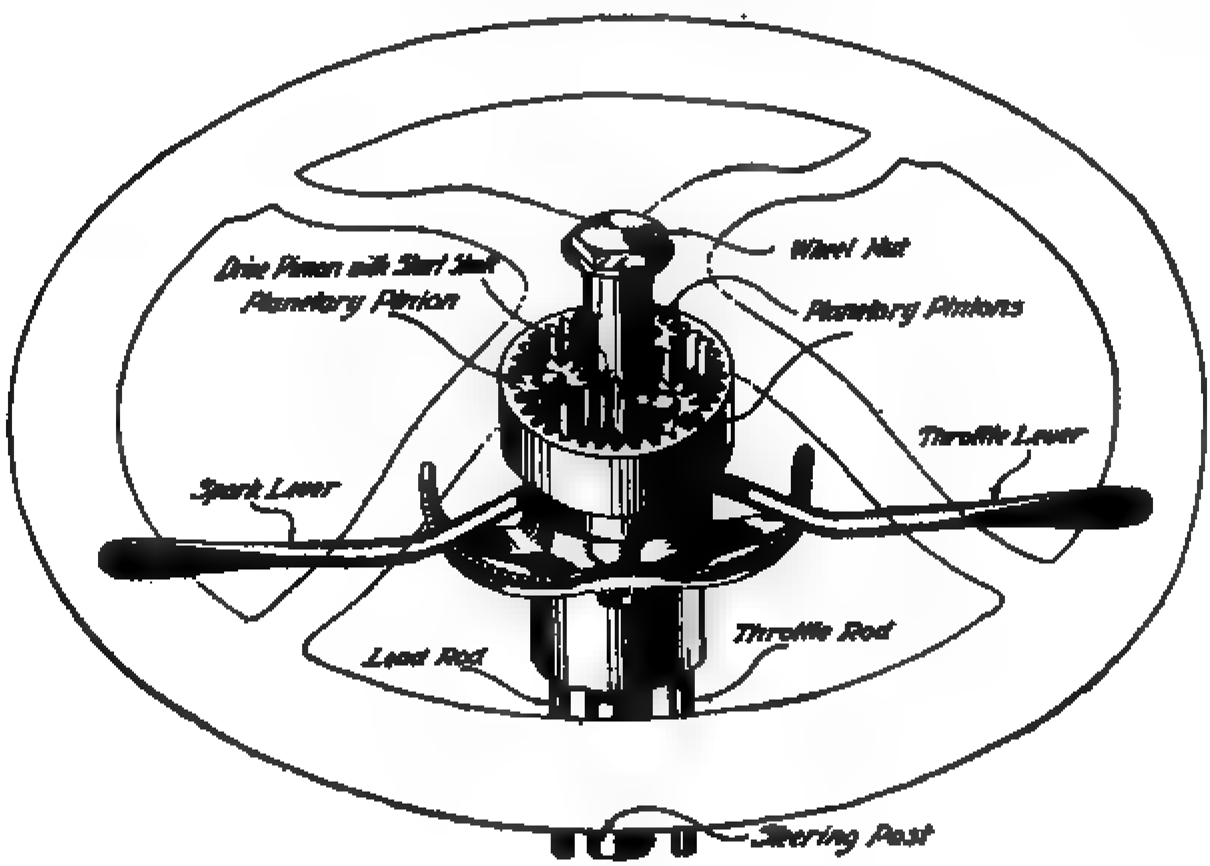



Fig. 331. Ford Planetary Steering Gear—An Unconventional Type

go. If the hand wheel is revolved from left to right, for example, the movement causes the three pinions mounted on the pins of the steering column to rotate from right to l
stationary internal gear turn th
taken by the three pinions. Th
it from right to left, and, as the
in the same direction, swinging
move from left to right, and to a
turning, or movement, of the ha
that the movement from left to
road wheels. If the driver desi
the wheel is turned to the left.

The drag link of the Ford steering gear [illegible] signs in that it is at right angles [illegible] two-thirds the length of the tie rod. [illegible] is provided with an arm carrying a bal[illegible] gear connecting rod, as it is listed [illegible] cap which fits over the ball of the steering [illegible] has a ball socket at its other end, which [illegible] rod. The tie rod, called the spindle connecting [illegible] nects the spindles, is provided with yoke[illegible] yokes are pivotally connected to the spindle[illegible] through them and through an eye in the spindle. The Ford drag link differs from others in usual practice in that it moves to the right and left, while those used on other cars move forward and backward. No provision is made with the Ford drag link for absorbing shocks or for automatically compensating for wear as usually is the case with the conventional type of drag link.

Fig. [illegible]

**Semi-Reversible Gear.** The steering gear [illegible] cars, particularly trucks ranging from [illegible] only be capable of operation with a minimum [illegible]

These discs present constant bearing surfaces to the recesses in the nut, and are provided with slots into which the projecting levers from the rocker shaft fit. The screw pulls the nut up or down in the housing, and there is no tendency for this nut to be moved sideways.

Fig. 333. Worm and Gear Steering Arrangement—Semi-Reversible

The levers projecting from the rocker shaft into the swivels which rotate in the lower part of the nut are in direct line with the screw, so that the push and pull of the nut is in a straight line.

**Removing Steering Gear.** To disassemble the majority of steering gears it is necessary to remove the unit. With the type shown

in Fig. 333, which is a semi-irreversible worm and gear, the removal may be accomplished by displacing the control levers at the top of the column and dropping the unit down through the frame. The adjustment of this type for end play is made by loosening the locking nut *A* and turning down the nut *B* until the play is eliminated.

## STEERING-GEAR ASSEMBLY TROUBLES AND REPAIRS

**Lost Motion and Backlash.** Lost motion of the steering wheel does not always indicate that the steering gear is at fault, for wear in the steering-gear assembly usually takes place first in the clevis pins, yokes, and connections of the drag link. The spindles, spindle bolts, and wheel bearings are factors. Despite the fact that the front road wheels are deflected but a few degrees the spindles, bolts, or bushings may be worn, as these parts are subject to radial and thrust loads. The spindle bolt, which does not move, tends to wear oval; adding to this tendency the wear of the spindle bushings, one has considerable lost motion to contend with. Wear of the wheel bearings contributes to the apparent lost motion of the steering gear as do the connections of the drag link. Taking all of these factors into consideration, and allowing but a small fraction of an inch for play of each worn part, the sum total may result in considerable movement of the hand wheel before the road wheels are deflected.

**Lost Motion in Wheel.** While there should be a certain amount of movement to the hand wheel before it actuates the road wheels, the lost motion, as a rule, does not exceed $\frac{1}{4}$ or $\frac{3}{8}$ inch when the gear is new. This amount is essential as without some free movement the steering of the vehicle would be tiresome. Wheels may be keyed or pinned to the column. When play exists as the result of a worn key, pin, or slots, the remedy is to re-cut the seats and make and fit a new key or pin. With some types of wheels the use of a wheel puller will be necessary to displace them. Another cause of lost motion, when the wheel is tight and linkage free from play, is a loose key retaining the worm or gears of the steering gear proper. A simple test of the hand wheel is to hold the tube, or post, securely and move the hand wheel. The amount of play in the drag link can be ascertained by grasping it about midway and trying to move it backward or forward or in the normal direction of travel. Hold the ball arm of the steering gear when making this test.

The amount of backlash present in the irreversible and semi-irreversible types of steering gears may be determined by disconnecting the drag link, grasping the ball arm, and moving it up and down and back and forth. Worn bushings in the steering-gear case are frequently the cause of movement of the column as a whole. Another component that should not be overlooked in the search for the cause of lost motion is the ball arm. Movement of this member on its shaft can usually be eliminated by tightening the nut.

## STEERING WHEELS

**Different Forms of Hand Wheels.** *Wood Rim.* A variety of material is utilized in the construction of the wheel, which has super-

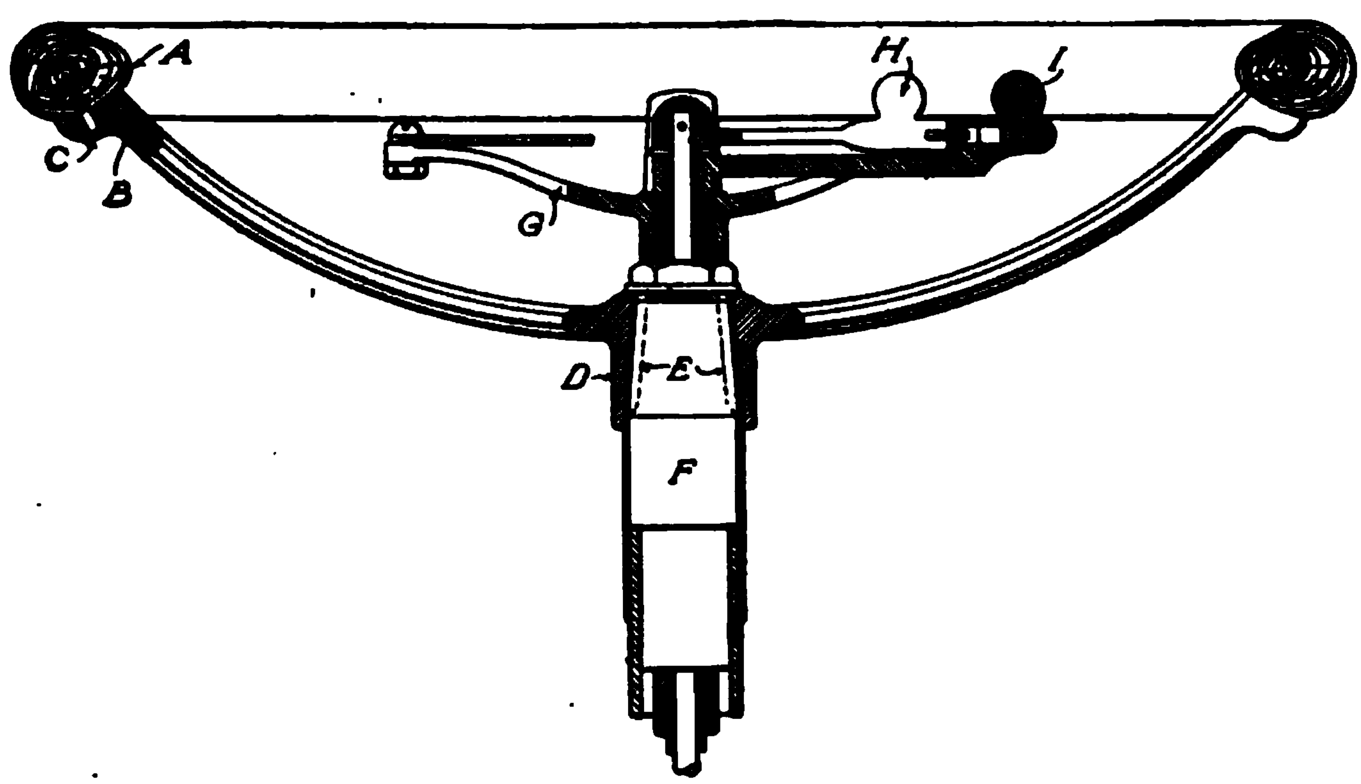



Fig. 334. Section through Typical Steering Wheel

seded the lever or tiller. The section or sections of the wheel or rim are circular, oval, or elliptical; the oval, or ellipse, is turned upward. The strength of the wheel varies according to the material used and the process of assembly. The all wood wheel has not the strength of a built-up wheel with a metal core, but it is simpler and cheaper to manufacture. With the exception of the molded rubber type of rim, the majority of the wheels, particularly those fitted to high-grade cars, are built-up. Mahogany, circassian walnut, and black walnut are the materials favored. The wood is cut to short sectors of an annular ring of about 2 inches in width and so glued together as to eliminate joints.

The method of attaching the rim to the spokes of the wheel spider is by screws, and this method is illustrated in Fig. 334. *A*

indicates the wood member, *B* the arms, or spokes, which have a boss through which the screw *C* passes into the wood. The hub of the spider *D* is attached to the steering post by two keys *E*.

*Metal Core with Wood Covering.* When the wheel design is made up of a metal core the ring is cast on the spider or integral with it. Coverings of wood concealing the ring are used, although with some types, a section of the ring may be noted. This type of wheel possesses great strength and the wood veneers can be secured at more frequent intervals than in the design previously described.

**Different Wheels for Commercial Use.** *Truck Types.* For the light delivery wagon, taxicab, and similar cars, no difference in the steering wheel is made, but when it comes to the heavier service, there is a need for a heavier wheel. This does not mean a heavier rim only, but a heavier, more rugged gear all the way through. The weight on the front wheels of a heavy truck is very great, and the tires, which are of solid rubber, may have frictional contact with the pavement of several inches in width. All this combines to make turning the vehicle from the driver's seat more difficult.

For this reason the driver must have a greater leverage, which means a larger diameter of the wheel. Then, too, the rim should be bigger in section in order to withstand the harder use of commercial service, and to provide for the large hands of the operators. Greater strain upon the rim of the wheel, on attempting to turn heavier weights with it, means that the rim must be fastened to the spider more securely. This means more arms, the four generally used for pleasure cars being increased to five for trucks. While this helps a great deal, since it provides five screws instead of four, it is not sufficient, and most of the big trucks today are equipped with steering wheels in which the rim is built over a central metal rim of the spider.

*Pleasure-Car Types.* Usual pleasure-car practice varies from 14-inch up to 16-inch wheels, while commercial car sizes begin at 16-inch and run up to 18-inch wheels on light trucks, and as high as 20- and 22-inch wheels on heavy trucks. Rim sizes vary considerably, a favorite for touring cars being an oval with from $\frac{3}{4}$- to $\frac{7}{8}$-inch vertical height and a length of about $1\frac{1}{16}$ to $1\frac{3}{16}$ inches. These figures have no connection with commercial work, the smallest being 1 inch and on up to $1\frac{1}{8}$ inches in height, with the long diameters varying from $1\frac{1}{4}$ up to $1\frac{3}{4}$ inches. For speed work, racing, and the like, it is usual practice

for the operator to wind the surface of the wheel with string, this giving a rough surface upon which the hands will not slip. This is practiced, too, by many truck drivers, who claim that the strains of steering the big vehicle are not felt as much when the wheel is thus wound.

To preserve the nice appearance of the steering wheel and still

Fig. 335. Molded Rubber Steering Rim on S.G V. Car
*Courtesy of S.G.V. Company, Newark, New Jersey*

give the roughened surface to which the hands will cling easily, even in wet weather, many manufacturers are making a wheel of molded rubber, the use of this material allowing the formation of the wheel in any desired section, as is seen in Fig. 335. As a concession to appearances, these wheels are usually made with a plain upper surface; the lower or under surface, however, being made in a series of depres-

sions and bumps, between which the fingers find a good resting place. This gives a good grip, as the under side of the wheel seldom gets wet.

*Folding Steering Wheels.* Although tilting steering wheels were introduced several years ago, they did not meet with favor until the Cadillac adopted them as standard equipment. The wheel, which is 18 inches in diameter and has an aluminum spider, is hinged to drop downward, a design facilitating entrance and exit at either side of the car and making it possible to attain the driver's seat without squeez-

Fig. 336. Hinge Type of Steering Wheel Used on Cadillac

ing. The Cadillac wheel is shown in Fig. 336, while that used on the King car, illustrated in Fig. 337, is of the tilting type. To operate the design, the wheel is turned until the wheel spider arm carrying the release button is convenient to the thumb of the right hand. The button is pushed to the right, and, by using both hands, the wheel is pushed forward and upward. The Herff type, shown in Fig. 338, is of the true hinged form; the rim is thrown up and out of the way, that is, the rim only, as the quadrant carrying the spark and

throttle levers remains. There are several other types marketed, but their working principles are similar.

**Throttle and Spark Levers.** In the usual case, the arms of the steering wheel have the quadrant for the spark and throttle levers fastened to them. The levers are operated within the space inside of the rim of wood and above the spider of metal; the latter is usually at a lower level by several inches, as shown in the figure. In Fig. 334, however, the quadrant is not carried by the spider arms, but on a separate framework *G*, or spider of its own, up above the hub of the wheel. Over this framework the spark and throttle levers *H* and *I* work, serrations of teeth in the quadrant preventing the levers from moving, except when they are sprung off by the pressure of the fingers operating them. In some cases, these teeth are done away with and friction surfaces are substituted; springs holding the contact surfaces together are so light as not to interfere with the moving of the levers by hand.

Fig. 337. Tilting Steering Wheel on the King Car

Fig. 338. Herff-Brooks Folding Steering Wheel

## STEERING ROD, OR DRAG LINK

**Operation.** By the steering rod, or drag link, is meant the member connecting the ball arm, or lever, of the steering gear to the lever attached to the steering knuckle. This is clearly illustrated in Fig. 339. The steering gear is marked *D*, the steering arm pro-

jecting down from it $C$, while the steering rod which connects the lower end of the arm with the lever on the knuckle is marked $AB$. $F$ is the knuckle pivoted in the axle, which carries the two-end lever $E$, one arm of which has the steering rod attached to it at $B$, while the other carries the cross-connecting rod joining the two knuckles together. Since the pivot point is fixed, any movement imparted to the knuckle must result in its swinging about the pivot point and carrying the wheels with it.

This movement is imparted by the steering rod to the end $B$ of the arm $E$.. The steering rod itself simply

Fig. 339. Typical Steering Arrangement on Pleasure Car

a constant level, although moving in a circle, the rod must have a universal joint at one end. This is really a necessity from two points of view: to allow the rear end to move up and down vertically while the front end swings around in a circle; and also to allow the front end to swing in a circle set in one horizontal plane, while the rear end remains stationary or practically so in that plane. In short, the two ends move continuously, each in its own plane, but the two planes never coincide—the one is always vertical, while the other always stays horizontal. This necessitates at least one universal joint. Many makers play on the safe side, and lower the cost of

production by making the two ends alike—a universal joint on each one.

**Types of Construction.** A glance at the construction shown in Fig. 340, and also in Fig. 341, shows a steering lever made with a ball end, or partial ball end, upon which the steering rod is hung. In this, the partial ball is formed in the center of a bar, the inner end of which is threaded and screwed into the steering arm, with a nut on the outside to prevent its backing out. The ball itself is made separately and slid on over the rounded end of the shaft, or axis. After this a sleeve is put on, followed by a nut which holds the sleeve up tight against the ball. The function of the sleeve is to give the spherical end of the rod plenty of play in a sidewise direction. This is a cheap form of construction, but could have been made in one piece had it been desirable or necessary to do so. Such a form has a metal-to-metal contact, which is hard upon both ball and socket, necessitating frequent and costly replacements. These replacements are obviated by backing the ball socket up with a spring or springs, as is shown in Fig. 341. This form of construction is now quite generally used; the socket of the ball in the inner end of the rod is set inside of a sleeve with a spring on each side of it. These springs not only take up the road shocks but the wear as well, the shoulder against which they rest being adjustable. In this figure, $J$ is the lower end of the steering lever with the ball end. This lever is mounted in the ball socket $G$. $A$ is the body of the steering rod, which is expanded at the end to a larger diameter, this being designated in the figure as $B$. Within this expanded portion, the sleeve $E$ at one end acts as a shoulder for the spring $F$.

Fig. 340. Steering Lever with Ball End

At the other end, the outside of the sleeve is threaded to receive the collar $C$ with the hexagon end $K$. Within this, a second spring $L$ holds the socket up to its position. The location of the collar $C$ determines the tension of the spring $L$, and this is locked in its position by the screw $V$. Should there be wear, which necessitates the moving of the ball toward the open, or left, end, the whole thing

is disassembled and a longer sleeve inserted in place of the one shown at *E*. On the other hand, ordinary wear is compensated for by taking up on the collar *C*, first loosening the lock screw *V*.

In Fig. 342, a rod is shown assembled at the top and disassembled into its components at the bottom. The two ends differ, one being

Fig. 341. Adjustable Form of Ball-End Steering Rod

but a simple yoke with a plain bolt through it, marked *D*. The other, however, is a ball end with an adjustment and with springs to take up shocks.

All these parts are marked in the figure and may be located by letter. The body of the rod is marked *A*, the expanded end *B*, which has a groove *H* cut in it. Into the inner end of this groove is fitted, first, the spring *F*; second, the two halves of the ball socket *G*; and

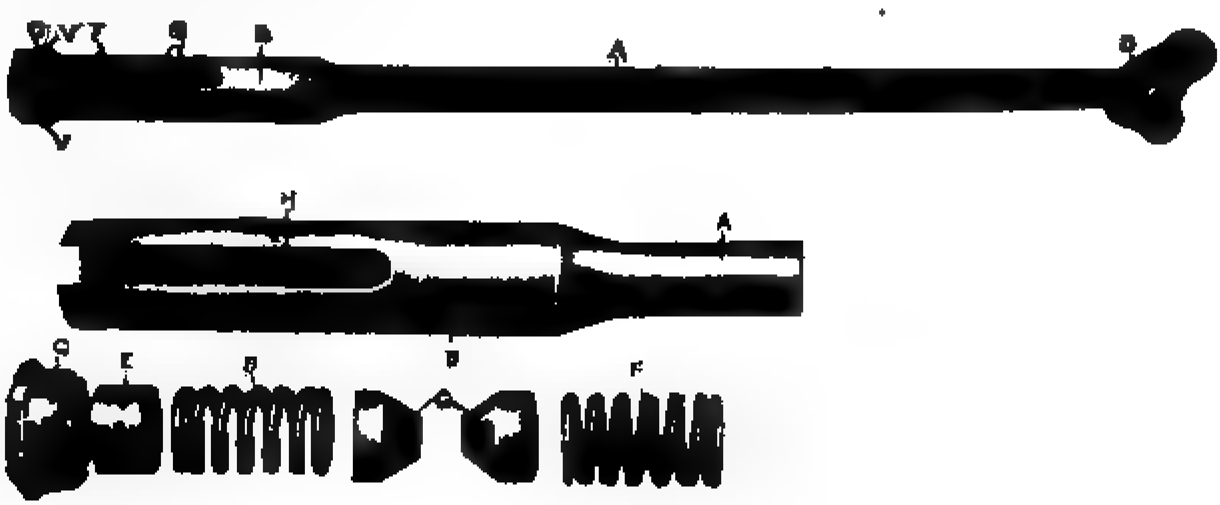


Fig. 342. Cross-Connecting Rod Assembled and in Parts

third, another spring. The sleeve *E* closes the outer end, and over the exterior is screwed the adjusting nut *C*. The nut and sleeve are held in place by the locking pin *V*, which passes through the outer nut, the shell end of the rod, and the inner spacing sleeve, the ends being riveted over to hold it in place. This form limits the adjust-

ment to a full half turn of the nut, while the pin would soon need replacement if much adjusting were done, as some of its length would be lost each time it was riveted over because of the chipping away to allow it to be taken out.

**Cross-Connecting, or Tie, Rods.** The object of the cross-connecting, or tie, rod is to connect the right- and left-hand steering knuckles so that the road wheels will be turned alike. The general practice is to place the rod back of the front axle, a location avoiding the possibility of damage if an obstruction in the road is encountered, but in some instances the tie rod is placed in front, as in Fig. 339.

Fig. 343. Finished S.G.V. Chrome Nickel-Steel Steering Knuckle and the Same before Machining

Fig. 344 Left Steering Knuckle of S.G.V. Car before and after Machining

The tie rod is made adjustable to compensate for any change that may be necessary to preserve the alignment of the wheels, and, generally, the rod is adjustable at either end. The yoke ends of the rods are made adjustable, screwing on or into the rod proper and secured by lock nuts or other suitable fasteners. The adjustment is easily made. Decreasing the length of the rod increases the gather, or distance, between the forward section of the front wheels, while increasing it causes the wheels to toe in. This applies to the tie rod behind the axle.

**Function and Shape of Steering Knuckles.** The steering knuckles serve as a pivot for the road wheels, enabling them to move in a horizontal plane. The design of the knuckle depends upon the axle, and the pair used on a car are different as one has a lever for carrying the drag link. Both have integral spindles to which the tie rod is attached. Figs. 343 and 344 illustrate the difference between the knuckles.

**Fig. 345. Packard Steering Gear Parts**

Fig. 343 shows a right knuckle, forged from a blank of chrome nickel steel, while the one at its side is the finished part. *A* is the place for the outer wheel bearing, *B* the position of the inner bearing, *C* the hole for the pivot, or knuckle, pin, *D* the upturned steering arm, and *E* the arm to which the tie rod is attached. Fig. 344 is an example of a left steering knuckle of the same pair, both before and after machining. The letters in Fig. 343 apply to this knuckle.

**Lubrication of Steering-Gear Assembly.** The proper lubrication of the steering-gear assembly adds to its life, but this work is not, as a rule, thorough. The steering gear proper should be packed with grease, the ball and socket joints of the drag link and steering-arm lever with a light grease; the clevis pins also should be lubricated. The steering-knuckle pins are provided with either grease or oil cups.

A point generally overlooked in the lubrication of the steering gear is the steering-post spark shaft and throttle-sector anchor tube, shown in the illustration at Fig. 345, which is of interest in that it illustrates the assembly of the Packard car. The post carries the control-box unit. The spark shaft and throttle tube frequently lack lubricant and should be cleaned and coated with a graphite grease before replacing when the gear is being reassembled. The lower extremity of the spark and throttle members carry levers or small bevel sectors which operate the linkage of the ignition apparatus and carburetor. Clamping screws are generally used to secure these parts.

Fig. 346. Front Drive and Steer on Homer Laughlin Car

## SPECIAL TYPES OF DRIVE

**Front-Wheel Drive.** In the conventional type of pleasure motor car, the energy of the engine is applied to the rear wheels which propel the car, the drive being a pushing one. A pleasure car, or rather a racing machine, with a front-wheel drive—which is a pull, and held by some to be more economical—was brought out several years ago but not marketed. During the latter part of 1916, a company was formed to market an eight-cylinder pleasure vehicle, utilizing a front-wheel drive and steer and a friction drive with an automatic pressure control.

*Difficulties of Transmission.* The Homer Laughlin car, a bottom view of which is shown in Fig. 346, makes use of an original type of

universal joint to transmit uniform angular velocity. Its design was brought about by the fact that the rate of transmission of angular velocity through a universal joint is not even when the shafts are at an angle. This is the fundamental difficulty every designer of a front drive has to overcome or suffer the twisting of the axle.

The front wheels and the flywheel must rotate at practically a uniform speed, at least through each revolution. The irregular rate of transmission through the universal joint must be taken up some-

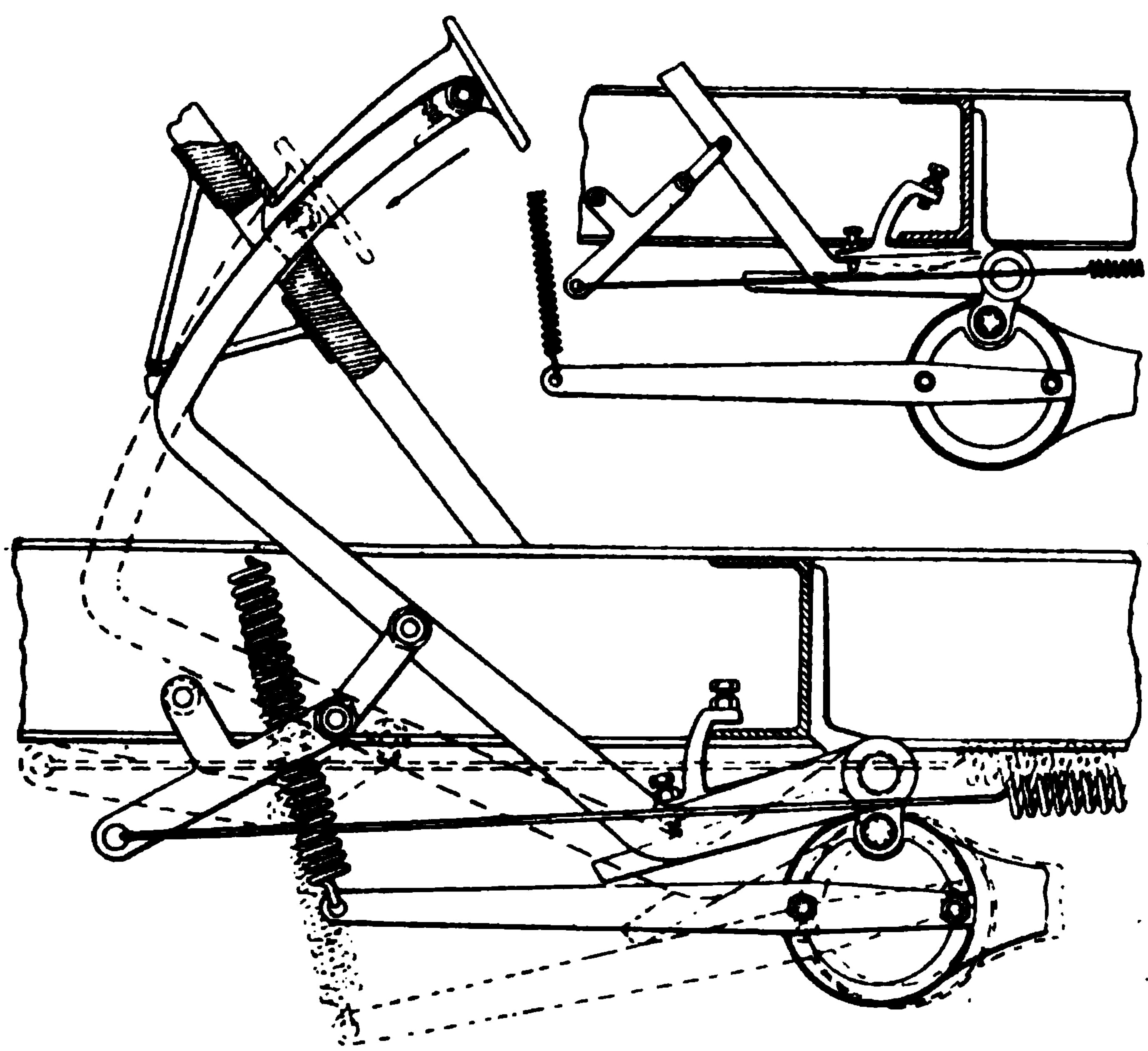


Fig. 347. Homer Laughlin Pedal Mechanism

where. The normal action of a universal joint at certain angles is to make four jerks in a revolution, as it has four fast points and four slow points. The Laughlin joint gives uniformity of rotation with 75 per cent on each side of normal, the difference being taken up by the flexibility of the transmission parts.

*Friction-Disc Transmission.* The transmission is of the friction-disc type, but the disadvantage of this form of drive—the fact that the control is reversed—is eliminated. The usual clutch control is provided, but the pressure is automatic. This pressure is obtained by an eccentric connection by means of which designers obtain irre-

versible application of spring pressure. The transmission locks at the correct pressure through the friction of the eccentric. The spring controlling the friction for driving provides the proper pressure for running, but it is not sufficient for starting or climbing long hills in the low gear. The pedal shaft operates a dog that presses down on the eccentric sheave extension. To de-clutch, the operator presses the pedal down, releasing the clutch. The pedal has two points at which it latches, providing extra pressure, and an extra spring is brought into service for the high and low speed. This spring operates through a toggle linkage. As the pedal rises, the applied power increases. When the car attains momentum, the driver depresses the pedal until it latches. The running pressure is sufficient to hold the engine in all gears except the low and reverse.

*Control.* Complete control is obtained through one gearshaft, the lever working forward for progressive, and back for reverse. Automatic latching is obtained in every gear, the latch working in sockets sunk in the jackshaft. Chain drive is employed between the transmission and front axle. The brakes are located on the rear axle. Fig. 347 shows the method of obtaining a conventional pedal control of the transmission through the irreversible application of spring pressure—one spring for ordinary service, the other for low gear work—controlled by the eccentric on the jackshaft of the driving mechanism.

**Four-Wheel Driving, Steering, and Braking.** The four-wheel drive—a construction in which all four wheels of the vehicle drive, and frequently steer and brake—is confined to commercial vehicles. A brief consideration of the actions which may have to take place at the same time in such an axle will give a very good idea of the problem which must be worked out. The wheels must be free to turn about the axle as an axis, being driven from their hollow centers; the wheels must also be free to turn about the pivot point as an axis swinging in a horizontal direction and must be driven steadily all the time. All the turning, swinging, and driving action must be outside of and beyond the spring supports of the chassis, since the body cannot turn; but the axles must at the same time support the springs. Further, if all four wheels are to carry brakes, they must be applicable at any and all times and at any and all angles of inclination of the wheels, either in a vertical or horizontal direction, and they must be so equalized as to apply equally to all wheels, no matter how the

force is applied to the system, and no matter in what position the wheels may be.

The advantage of the four-wheel drive and with it the four-wheel steer and brake is granted by eminent engineers, as is also its

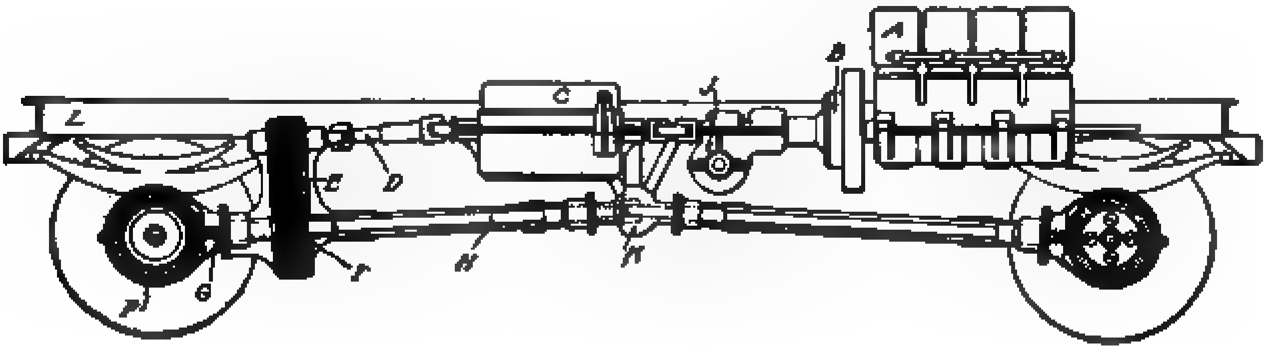


Fig. 348. Side View of a Four-Wheel Drive, Steer, and Brake Motor Truck

necessity for heavy commercial trucks, but its use has not been extensive for the simple reason that it is a complicated arrangement at best. In many cases, the design has been so complicated and unmechanical as to cause failure, and the reports of these troubles have given the four-wheel driving, steering, and braking device a sort of visionary air, so that any one talking of it is supposed to be a dreamer. Such is not necessarily the case, for many different practical four-wheel combination driving, steering, and braking devices have been brought out, built, tested, and proved efficient.

A number of four-wheel designs for commercial cars are being marketed, and have proved the contention of their makers that they are economical in operation and maintenance.

**Four-Wheel Steering Arrangement.** With the design shown at Fig. 348, steering knuckles are eliminated, the wheels being con-

Fig. 349. Details of Axle of the Four-Wheel Drive Truck Shown in Fig. 348.

nected to the axle ends through the medium of vertical trunnions. These trunnions bear on the wheel ball-bearing ring, which is ample in diameter and turns freely because of its size and the use of ball

bearings. Within this ring, the axle terminates in what is practically a universal joint, driving through to the outside of the wheels. The wheels are thus free to run about a point in the axle ends, at the same time taking their power through the inside rotating shaft. Fig. 349 illustrates one of these axles with the parts lettered. Here *H* is the point of attachment of the driving propeller shaft, *G* the cast-steel one-piece case, *F* the differential gear within the large driven bevel gear *O*, *MM* the vertical trunnions upon which the wheels rotate, and *NN* the universal joints which drive the wheels.

How the steering is obtained is shown in Fig. 350. At the front of the chassis is the steering wheel *P;* turning it partially rotates the longitudinal shaft *Q*, which extends the length of the chassis. This shaft carries levers *RR* near its two ends, which are connected to

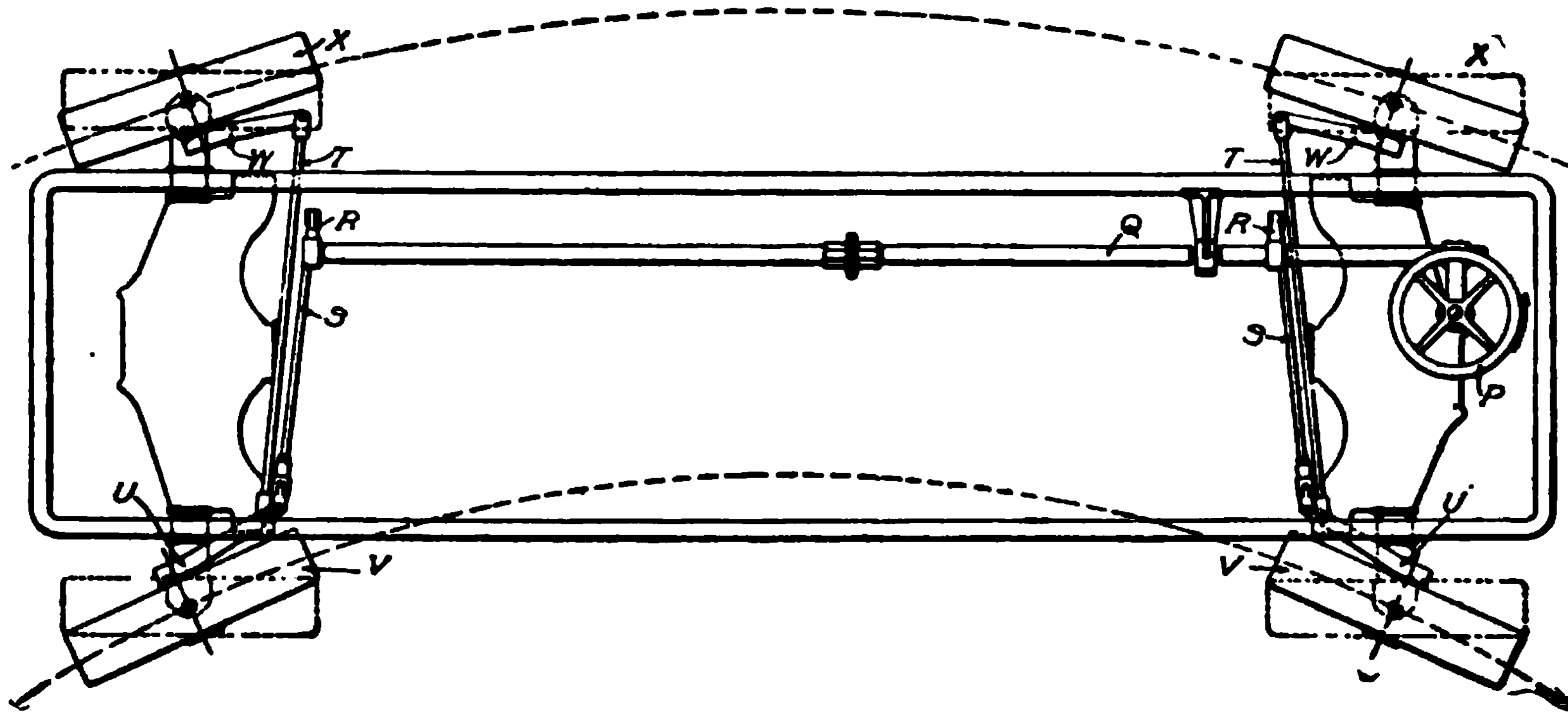



**Fig. 350. Diagram Showing Steering Action of a Four-Wheel Drive Truck**

the steering rods *SS*. These rods connect to the steering levers *UU*, which are fixed to the wheels themselves instead of to the steering knuckles as in the ordinary case, for this car has no steering knuckles. In addition to the steering rods attached to the longer of the two steering levers, there is a cross-connecting rod *TT* at each end, which connects the two steering levers. Thus, when the levers *RR* move the rods *SS*, and through these the levers *UU*, which in turn move the wheels *VV*, the rods *TT* also come into play and move the levers *WW* and the wheels *XX*. Therefore, the movement of the steering wheel in any given direction, as to the right, turns all four wheels, the front two to the right, and the rear two to the left so that they form arcs of the circle in which the front ones are turning. The truck thus makes the desired turn to the right in one-half the

distance or time of the ordinary truck. Four-wheel steering then has the advantage over two-wheel, or ordinary, steering, of requiring only one-half the space and one-half the time to accomplish a given turn. The vehicle described would turn completely around in a circle of 40 feet, the outermost circle shown in Fig. 350 being 56 feet in diameter.

*Chain Four-Wheel Drive.* Fig. 351 clearly illustrates a bottom view of the Hoadley four-wheel drive, four-wheel steer, and four-wheel brake truck. The power of the engine is transmitted through shafts, gears, and universal joints to the differentials; there is a third differential in the gear box at the center of the frame. Final drive is by chain; both ends of the truck are exactly alike in so far as the four-wheel drive is concerned, and the fifth wheels run in ball bearings. Steering is accomplished by means of worm gearing, the shaft being clearly shown, and both sets of wheels are steered simultaneously.

*Jeffery Quad.* An example of the successful development of the four-wheel drive is the Jeffery Quad, Fig. 352, which has given an excellent account of itself in government work. In this type it will be noted that the inclined driving shafts, shown in Fig. 348,

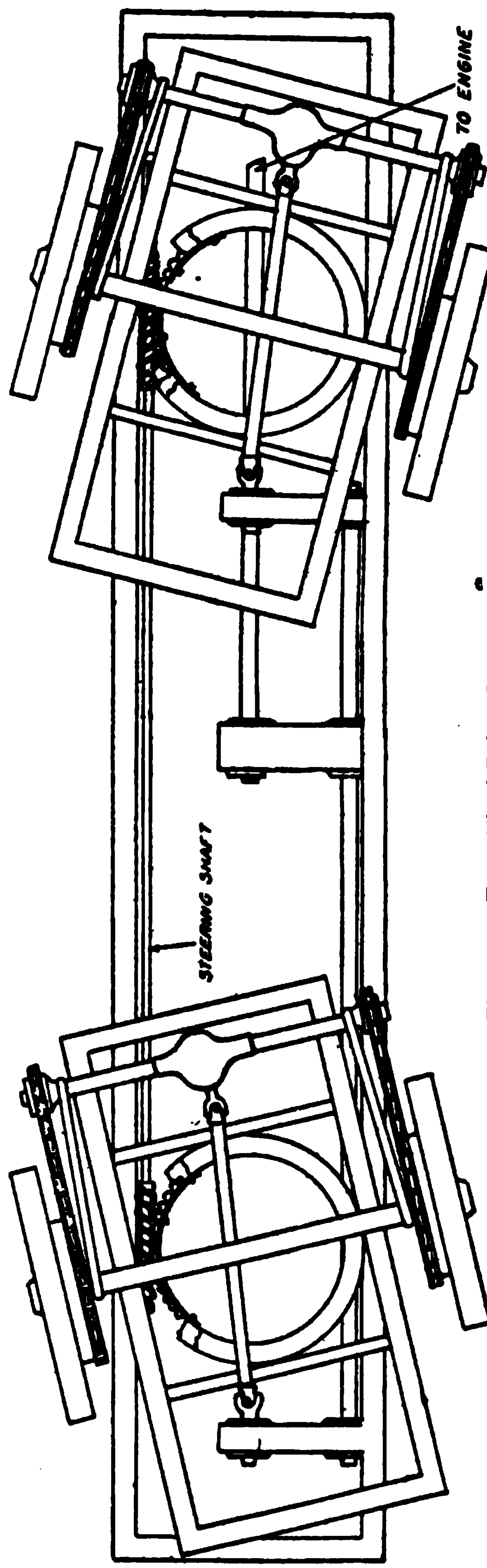



Fig. 351. Four-Wheel Drive, Steer, and Brake System

have been carried up to the gear box with a universal joint on either side. This construction has resulted in a much more inclined shaft in each case, but it has also eliminated the tail shaft *D*, the use of a silent chain *E* with its housing, the central universal joint, and the spherical bearing *K*, and, in addition, it has simplified both shafts.

In the four-wheel drive vehicle the engine was placed on the center line of the car; on the Jeffery it is set off to one side, while the two driving shafts to the front and rear axle, which form a continuation of each other, are set off to the other side. This result is produced by making the transmission very wide with three side-by-side shafts, as shown in Fig. 353. The engine drives the splined shaft *A*, on which are gears that transmit the rotation to the intermediate shaft *C*, which through the final gears *E* and *F*, drives the final shaft, which is in two

**Fig. 352. Plan View of the Jeffery Quad, Showing Disposition of Units**
*Courtesy of Thos. B. Jeffery Company, Kenosha, Wisconsin*

parts, *B* driving one pair of wheels, *G* driving the other pair. Note that the differential has been incorporated in this type of drive, so that it is possible to have a different drive for the front wheels from that for the rear wheels.

The rest of the construction is too simple to require a detailed description beyond the simple statement that the gear box gives four forward speeds and one reverse. When the two ordinary shifters are in the neutral position shown, reverse is produced by shifting the double reverse gear on shaft *D* along until its left-hand member meshes with the second-speed gear on shaft *A* and its right-hand member with the low-speed gear on shaft *C*.

Universal joints fit on the two tapers *B* and *C* with shafts inclined to the two axles. On top of the stationary axle of the I-beam

section is fixed a small box which contains the bevel gears and an additional differential with suitable bearings, the whole being enclosed. These can be seen in Fig. 352, that on the rear axle being

Fig. 353. Plan View of the Transmission of the Jeffery Quad, Showing the Shafts for Both Axles

plainly shown, while the one in front is partly obscured. This member is shown in detail in Fig. 354, which gives the longitudinal section along the driving shaft at the left, in which the axle *H* is noted, the bevel gear *I*, and the bearings for radial and thrust loads

Fig. 354 Sections Showing Bevel Drives at the Axles on Jeffery Quad

at *J* and *K*, respectively. The driven shaft is seen at *L*, with the sleeve *M* around it, the sleeve being used to drive to the differential case, since the larger, or driven, bevel *C* is not sufficiently large to house the differential *P*.

Fig. 355 is a diagram showing the details of the axle end and wheel construction. In this, *H* is the I-beam section of the axle bed shown in Fig. 352, and *N* one of the shafts, which carries at its end the universal joint *Q*, with the end of the shaft extending beyond the joint *R*. The latter carries the spur gear *S*, which meshes with

Fig. 355. Section through a Wheel and Axle End of the Jeffery Quad, Showing Method of Driving and Steering

the internal gear *T* fixed to the wheel and drives the vehicle in this manner. It will be remembered that this is not necessarily a front wheel, but any one of the four.

The wheel turns on the spindle *U*, which is part of the steering knuckle *V*; this knuckle turns upon the pivot *W*. The lever which

turns the wheel is attached at $X$, the pair (either both front or both rear wheels) being connected by means of a cross-rod; at one end of this rod there is a connection to a rod which runs the entire length of the chassis. This rod is operated by means of the steering gear, and imparts the same motion to the front wheels as to the rear, except that the two are in opposite directions, that is, front wheels turn to the left and rear wheels to the right, so that they will follow around in a correct circle.

*Advantages of Four-Wheel Drive.* It is claimed for the four-wheel drive that its four-wheel steering reduces the mileage traveled to the minimum in that the car can run closely to corners and travels less in crowded traffic, in turning around, and in approaching and leaving loading platforms. The push of the rear wheels and pull of the front wheels enables it to surmount obstacles instead of bumping over them, and its greater traction permits it to travel soft roads not easily negotiated by the rear-drive type of trucks and cars. The four-wheel drive type will turn in a 48-foot circle, and, with its locking differential, obtains traction on slippery roads.

**Electric Drive.** When the final drive is electric, or when the source of power is an electric motor, the matter of four-wheel driving is much simplified, the wheel carrying the electric motor attached directly to it and turning with it about the knuckle pin. Both wheel and motor are turned by means of a worm and gear above, the wheel being attached to the upper end of the steering-knuckle pin prolonged. Turning this turns the wheel and motor.

This steering wheel is turned by the worm, which is on one end of a cross-shaft. This shaft is carried in bearings above the stationary bed of the axle and has near the center a bevel gear that meshes with another bevel, which is, in turn, attached to the lower end of the steering post. Turning the steering wheel turns the post and the bevel gear, which turns the bevel pinion and with it the worm shaft. The shaft turns the worm and the worm wheel which actuates the road wheels. The driver thus has a triple reduction between himself and the wheels, giving him this much advantage in steering: there is the leverage of the wheel of large diameter, the ratio of the sizes of the two bevels, and the ratio of reduction of the worm gearing, which, in addition, is irreversible. The steering gear is thus eliminated and four simple gears substituted for it.

*Couple-Gear Type.* In the Couple-Gear wheel, which is an American product, the motor is placed inside of the wheel—a type especially designed and constructed for this purpose. With the motor in this position, the wires enter through the hollow hub, altering its construction very materially. As compared with the electric motor on each wheel, previously described, this form has the advantage of greater simplicity, fewer parts, superior appearance, and protection against the elements, while the enclosed position of the motor, which is the most delicate part of the machine, protects it against road obstructions and accidents. This arrangement also simplifies the steering problem, since the car is steered just the same as any other truck, much of the complication incident to an electric motor on each wheel being eliminated.

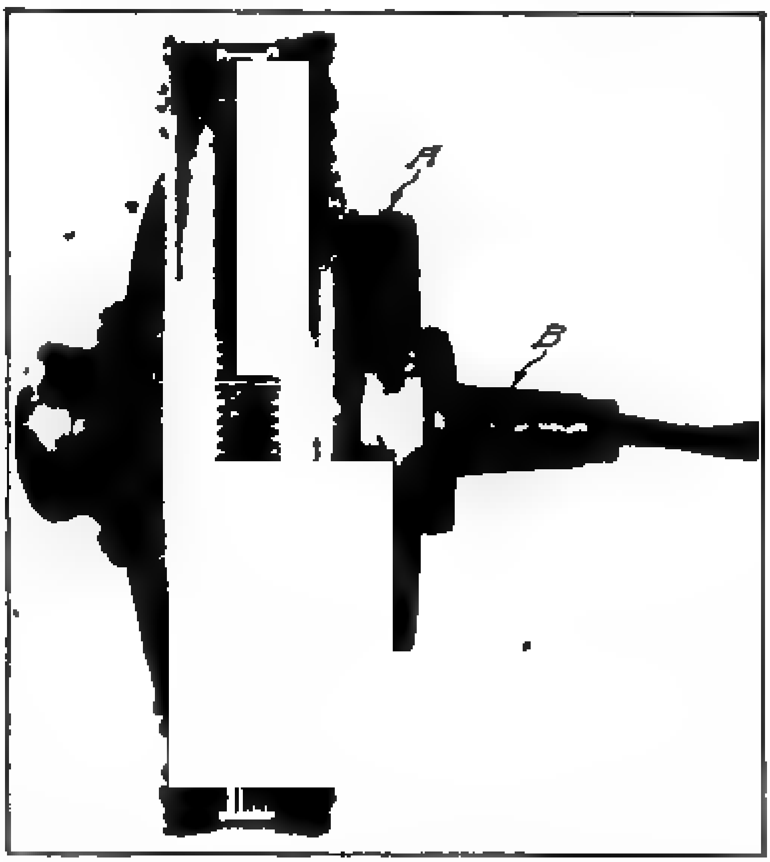


Fig. 356. End View of Couple-Gear Electrically Driven Wheel with Tire Removed

Fig. 356 is a view of the wheel with the tire removed and the whole disconnected from the axle ends. Aside from this, it is complete and ready for use. Note how the axis of the motor is set at a very slight angle, just sufficient to allow a pair of very small driving gears at the two ends of the armature shaft to drive on opposite sides of the wheel. The wheel is assembled with a pair of driven gears on either side, these being separated a comparatively small distance, about 2½ to 3 inches. As stated, the armature shaft has a small bevel pinion on each end, each of these meshing with the driven gears, but on opposite sides. It is this arrangement which gives the device its name of Couple-Gear. In this figure the brake band has been removed, but the brake drum will be seen just inside the wheel at *A*. Beyond this is noted the spindle *B*, which is made hollow for the wires from the battery and turns in a bearing on the axle.

In the second illustration, Fig. 357, an axle, either front or rear, with the wheels removed, is presented. In this cut the left wheel is entirely removed, but the one on the right shows the axle spindle *B*, the method of fixing it in the axle support at *C;* the armature housing *D* is normally within the wheel and not visible. One feature peculiar to this arrangement is the steering, which is effected by means of a vertical post with a small spur gear at its lower end *E*. This meshes with a curved rack *F*, which is machined on the outside of a pivoted member *G*, to which a pair of arms are attached. One of these arms *H* has a rod *I*, which runs to and operates the right-hand spindle *B*, while the other *J* has a similar rod *K*, which operates the left-hand wheel. When all four wheels are to be driven in this manner, the post is vertical, but the connection with the rack *F*

Fig. 357. The Couple-Gear Axle and Parts, Showing Method of Operation
*Courtesy of Couple Gear Freight Wheel Company, Grand Rapids, Michigan*

becomes horizontal, with a continuation to the rear axle which operates the various arms, levers, and rods there in the same manner.

This particular system is used for heavy commercial work only, and in this it has been particularly successful as a tractor, a front axle and a pair of wheels being substituted for those of a heavy trucking wagon. Then, with a sling under the body or beneath the driver's seat for the batteries, and with proper wiring, control levers, and steering wheel, the truck becomes electrically driven.

## FRONT AXLES

### TYPES

**Classification.** Generally speaking, front axles may be divided into about five classes: the Elliott, the so-called reversed Elliott, the Lemoine, the front-drive form, and the fifth-wheel form.

These typical forms of axles are themselves subject to further subdivisions. For example, there are many different forms of Elliott axles, each manufacturer having what is practically his own form. Again, the Lemoine, when used by other firms, has been built in a practically new form, taking the second maker's name. Thus the form of front axle made by Lemoine for Panhard is so different as to be called the Panhard, and not the Lemoine. The same is true of the Lisses axle made by Lemoine. In this country, it is claimed that the axles made by Timken are sufficiently different from the Elliott and reversed Elliott, from which the principle was taken, as to deserve the name of Timken axles. It should be borne in mind that in the following description of the various axle types the forms of material, and the shape, size, and kinds of bearings used do not alter

Fig. 358. Elliott Type of Front Axle and Steering Knuckle

the principle upon which the axle is constructed, although they do alter the appearance.

**Elliott Type.** In general, a front axle consists of a bed, or axle center; a pivot pin or knuckle pin upon which the knuckles may turn; and the knuckles themselves with the attachment for turning them. The Elliott type, Fig. 358, the form in which the end of the axle takes a U-shape, is set horizontal and goes over the knuckles. The knuckles have plain vertical ends bored for the pivot pin, which passes through and has its bearing in the upper and lower halves of the axle jaw. In this form, the thrust comes at the top, where the axle representing the load rests upon the top of the knuckles that represent the point of support.

**Reversed Elliott Type.** In the reversed Elliott front axle, as the name would indicate, the action is just reversed in that the axle end

forms a straight vertical cylindrical portion bored for the pivot pin, while the knuckles are so formed as to have jaw ends which go over the axle ends. The thrust comes at the bottom of the knuckle, where the axle bed rests upon the upper face of the lower jaw of the knuckle, the axle representing the load and the knuckle the support, just the reverse of the previous case.

This will, perhaps, be made clearer by illustrations. In Fig. 358, as already mentioned, the axle has the jaw ends, and the thrust comes at the top. This is indicated in the figure by the letter *A*, which calls attention to the thrust washers at the top. Fig. 359 shows an axle of the reversed Elliott type, this being the front axle

**Fig. 359. Reversed Elliot Type of Front Axle and Steering Knuckle**

for a heavy truck. In this the thrust washers *A* are at the bottom, and are of hardened steel, ground top and bottom to a true surface; the upper surface is doweled to the axle, while the lower is doweled to the knuckle. This form has the real advantage of concentrating all of the difficult machine work and assembling it into one piece, the knuckle. The Elliott type, on the contrary, makes the knuckle and axle difficult pieces to handle in the machine and afterward, this being shown in the cost. Ease of machining the bed of the axle is a great advantage, for the axle will average about 44 inches in length for a standard tread of 56½ inches, and longer for wider treads, up to a maximum of about 48 inches for the wide-tread standard in the South.

The ordinary automobile machine shop is not fitted up for work of this size, particularly in machine tools other than lathes, and this job could not be done on a lathe. The result is that it becomes a task to handle it, necessitating special and expensive rigging for that one job. This was the case with the axle shown, a boring mill of the horizontal type and a large size milling machine being used on it. Both of these had to have special fixtures, which were useless at other times, to hold and machine these parts. At that, this job was much easier than an axle of corresponding size in the Elliott type would have been.

**Lemoine Type.** The Lemoine type of front axle differs from those described in that the axle proper bears upon the top or bottom of the knuckle-pin part of the knuckle, the two being made as one; that is, an extension or a jaw of the axle does not support the knuckle as with the Elliott type. When the steering knuckle of the Lemoine type is mounted below the axle stub, the latter is carried higher than with the reversed Elliott, so as to rest upon the top of the knuckle. An advantage of the construction from a manufacturing viewpoint is the cost of machining. With this design, the thrust load is practically entirely at the bottom upon the knuckle, which also must take all side loads; it is fastened in a sidewise direction at but one point—the bearing in the axle. The side shocks are taken on the end of a beam fixed only at the other end, whereas with the other types, the load is distributed between two supports, or divided equally over two sides, the point of support being midway between them. With the Lemoine type discussed, the bottom bearing must compensate for radial and thrust loads—a difficult condition to meet.

Fig. 360. Inverted Lemoine Type of Axle as Used on Overland Cars

While the design is easy to machine, assemble, and handle, its disadvantage is that the knuckle has a double duty, having, as it does, both radial and thrust loads to care for because of its one-piece construction. This type of axle is, however, very popular with foreign designers.

*Inverted Lemoine.* A novel type of axle has been created in the 1916 Overland car, Model 75, called an inverted Lemoine. In this type, as Fig. 360 shows, the wheel spindle, or stub axle, is at the top of the steering knuckle instead of at the bottom as in the case of the regular Lemoine type. The knuckle has a single, fairly long support in the end of the I-beam front axle, the forging being much simpler on this account. In fact, this makes the axle nearly straight, which doubtless accounts in large part for this unusual design. One real advantage of this design is that it allows the car weight to be low in relation to wheel bearings, thus assisting in steering.

Fig. 361. Novel Front Axle Design Used on the New Light-Weight Marmon
*Courtesy of Nordyke and Marmon Company, Indianapolis, Indiana*

**Marmon Self-Lubricating Axle.** The new Marmon front axle, Fig. 361, is of the inverted Lemoine type similar to the Overland, shown in Fig. 360, but at first glance it looks quite different. For one thing, the bearing in the axle end is different, and in this lies an exclusive and valuable feature. The stub-axle pivot pin, made integral with the stub axle, is placed in a split bushing, which is a tight fit at the bottom—where the thrust collars are formed in it—and at the top, but not in the middle. When this bushing is in place, the knuckle and bushing are forced into the axle end from above, and a kind of hub cap screwed on at the bottom. This holds it permanently in place.

Near the middle of the split bushing there is a narrow slot to which a central bolt hole is connected. On being assembled, the inside is filled with lubricant, which cannot escape; but, as it wears away, the central bolt can be removed, more lubricant can be poured in until it is full, and the bolt replaced to prevent leakage. In this way the axle is self-lubricating, and, as the oil is used up very slowly, it needs practically no attention.

Fig. 362. Front Elevation of Car, Showing Camber of the Front Wheels

Like the Overland, this arrangement of the axle end brings the axle down low, relative to the weight, and consequently steering is made easier. The lowering of the axle also brings the points of spring support down and thus lowers the whole car.

**Camber Somewhat Complicates Axle Ends.** All front wheels are dished, that is, the spokes do not lie in a flat plane but in the form of a cone, with the point of the cone at the outer end of the hub and the base of the cone at the rim of the wheel. Now all roads

and most all pavements are made with a camber. The center of the road is made higher than the sides so that the road will drain. It is necessary, in order to have the lower spokes plumb or perpendicular to the road surface, to throw the center line of the wheel out of the vertical plane 2 or 3 degrees. This offset is also called camber, and it complicates the construction of the axle ends to such an extent that they must be machined with this slight angle either in the knuckle or in the axle, or distributed over the two places.

Fig. 362 shows the effect of this camber upon the front appearance of the car, the slight angle of the front wheels giving the car a bow-legged appearance.

**Gather Further Complicates Axles.** What the carriage men term "gather" further complicates the axle ends. This is the practice of setting the axle so that the front wheels are closer together at the front than at the rear, that is, they toe in. The idea of this is to make steering easier and, more particularly, to make the car self-steering on plain, level, straight-ahead roads. It is scarcely noticeable from in front, but is from above. Although many cars still have it, it is not used as much now as formerly.

## MATERIALS

The materials utilized for front axles include castings of steel, manganese bronze, iron, and other metals, in the form of forgings, drop forgings, drawn or rolled shapes, and pressed shapes. Wood has been but little used and only in the past.

**Cast Axles.** Castings for front axles have been looked upon with grave doubt and fear by designers and owners, because of the fact that road shocks are more severe for front than for rear axles, and because of the fear that a casting may have a blowhole or some other defect. In addition to the natural distrust of castings for this work, it was feared that such material would crystallize more quickly than would a better and more homogeneous material like steel. There is, of course, a certain amount of crystallization in all materials, but far less in a close-grained fine-fibered structure like forged or rolled steel than in any form of casting. Aside from this, castings present many other advantages which are well worth while. Thus, the spring pads may be cast integral with the axle with practically no extra charge, while the same forged integral with a drop-

forged axle may easily add several hundred dollars to the cost of the dies. Again, with casting patterns, the fillets may be changed easily to give a greater section here or to reduce a section there, while a similar action with any forged axle means a new set of dies, costing perhaps $600. There are many other machining helps which may be provided in cast axles without any extra cost.

Notwithstanding these many advantages, the casting for the front axle has been and is distrusted, and the makers who have used it have flown in the face of popular prejudice, for the public has mistrusted it even more than the makers. For this reason, the casting has been little used, and the writer fails to recall a single car with a cast axle now on the market.

**Forgings.** Forgings, as distinguished from drop forgings, are much used for good front axles, but are expensive. The writer knows of one excellent truck builder, striving to build the best truck in the world, who is using a hand-forged front axle, the end of which is shown in Fig. 359. It is forged down from a 6-inch bar of selected steel and the ends worked out so as to leave the bed proper a 2½- by 2½-inch section, which later has been increased to 3 inches square. This made a very costly piece of work, but the stand-up qualities shown in actual work more than made up for it as long as people could be found to pay the price demanded for a truck made along these lines.

Many smaller makers follow out the same scheme, the lighter work allowing the axles to be forged up much more quickly, more easily, and more cheaply. The smaller the amount of material to be heated, the less difficult will be the work, and the more quickly will progress be made. The general trend of axle practice today, however, is to turn over the axle job to specialists in that line, most of whom employ drop forgings, drawn- or rolled-steel tubing with drop-forged ends, or similar rapid-production forms of construction.

**Drop Forgings.** Drop forgings are now more used than any other form, although the first cost is great, for the dies must be very carefully worked out in a very high grade of steel; the result is a large expense of possibly $600 to $750 before a single axle is turned out.

As a matter of fact, with drop forgings, after the die is once made, the axles may be turned out rapidly, accurately, and with little labor and cost. Given the dies, therefore, there is no doubt that this method produces an axle at a very low first cost. Moreover,

the method itself produces better quality, for any process which works steel or wrought iron over and over again improves its quality, provided the steel is not burned in the process of heating. Not only are the majority of axles made of drop forgings, but of those not so made some part is almost sure to be a drop forging, as, for example, those made of steel tubing which have their ends or other parts made by the drop-forging process. In Fig. 363 is shown a drop-forged axle used on a truck.

**Tubular Axles.** The I-beam section of front axle is universally used, and while the tubular type formerly enjoyed some popularity, its use today is confined to a very few vehicles. When employed, its ends are drop forged or drawn, or rolled steel may be used with the ends welded or otherwise secured. The disadvantage of the tubular type is the fastening of the ends which is more or less offset by the lowered cost of material.

Fig. 363. Typical Drop-Forged Axle Used on Truck

*Drop-Forged Ends.* Nearly all the ends for axles made in this way are drop forgings, very few castings being used, while the spring pads, or spring seats, as they are sometimes called, are split into upper and lower halves and bolted on.

The loading conditions of all front axles are such that the load rests on the axle at two points inside of the supporting points—the wheels. Thus, the continual tendency of the load acting downward and of road shocks acting upward is to bend the center of the axle still further downward. Since a tube which has been bent once has been weakened, it follows that this tendency to weaken it presents a further source of trouble.

**Pressed-Steel Axles.** The pressed-steel type of axle, which made its initial appearance in 1909, and is not generally employed, consisted of a pair of pressed-steel channel shapes—one being

slightly larger than the other—set together with the flanges inward so as to present a box-like shape. When thus arranged, the two sections were riveted together by a series of rivets running vertically along the center part of the channels. The ends consist of drop forgings, machined to size or space between the channels when assembled, and then set into place between the ends and riveted. The pressed-steel construction obtained a secure attachment to the bed. This axle was of the Elliott reversed type.

**Change of Axle Type Simplifies.** Often the change from one type of axle to the other is not made because the latter is better but because of some incidental saving in the manufacture. Thus, in

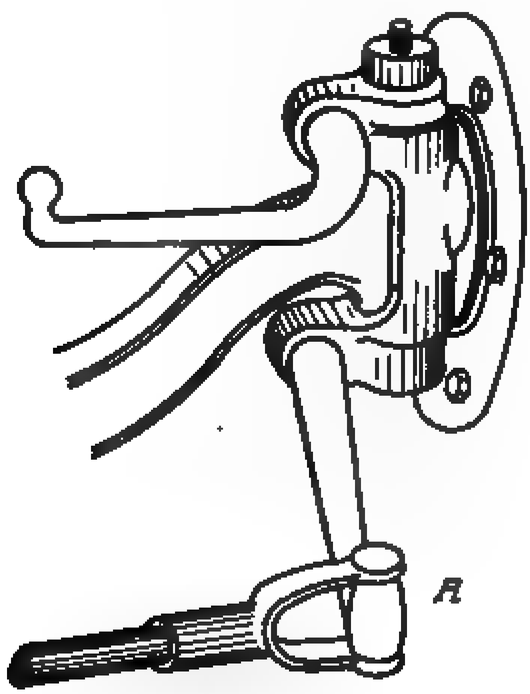



Fig. 364. Differences in Construction of Reversed Elliott and Elliott Types of Axle Knuckle

Fig. 364, we see the reversed Elliott type at the left at *A* and the Elliott type at the right at *B*. From a manufacturing point of view, the former is much cheaper to construct, for the axle and knuckle costs would just balance one another, but the forging and machining of the one-piece steering arm shown in *B* would be more than double that shown in *A*. Moreover, the number of dies and their cost would be about three times as much, while the customer would have to be charged two or three times as much for repair parts. That is, in a modern low-priced car, produced in tremendous quantities, the advantages and costs connected with the two-piece steering arm of *A* would influence the choice of that design, regardless of other advantages or disadvantages.

## AXLE BEARINGS

**Classification.** Thus far nothing specific has been said about axle bearings. These are, according to construction, of three kinds: plain, roller, and ball. From the standpoint of the duty which they are to perform, bearings may be divided into radial-load and thrust bearings, all three forms mentioned above being used for both purposes, but arranged differently on account of the difference in the work. Each one of the three classes may be further subdivided. Thus, plain bearings may be of bearing metal or of hardened steel, or they may even be so constructed as to be self-lubricating. Again, plain bearings may mean no bearings at all as in the old carriage days when the axle passed through a hole in the hubs, and whatever wear occurred was distributed over the inside of the hubs, resulting

Fig. 365. Front Axle End, Showing Roller Bearings for Wheel and Steering Knuckle

after a time in the necessity for either a new set of hubs or a new axle, or for the resetting of the axle, so that the hubs set further up on a taper. Roller bearings may be of several classes, some makers using both straight and tapered rollers. In addition to these there are combinations of the straight and tapered types, and bearings with two sets of tapered rollers acting back to back, the action being that of straight rollers, with the end-adjustment feature of the tapered type. There are also many types of ball bearings, as, for example, plain ball bearings—those working in flat races, those working in curved races, those working in V-grooved races, and single balls working alone. There are also combinations of balls in double rows.

**Roller Bearings.** Fig. 359 shows the use of tapered roller bearings for the hubs and of hardened-steel thrust washers for the thrust load, the figure showing, in addition, a plain brass bushing in the axle for the knuckle pin to turn in. In Fig. 365 is shown a more elaborate use of roller bearings of very excellent design. In addition to the axle bearing, it will be noted that the top bearing of the steering knuckle is of the roller type.

**Ball Bearings.** Although there is a growing tendency to utilize a short adjustable type of roller bearing, many designers favor the ball bearing. The two most common forms are the cup and cone type, which cares for radial and thrust loads, and the annular form which

Fig. 366. Front Axle and Steering Knuckle of Superior Construction

is suited for supporting annular loads. The annular form is not adjustable, and when it wears it must be replaced with a new bearing. The cup and cone type is adopted by makers of low-priced and medium-priced cars, has an angular contact, and is adjustable.

In some instances, particularly with high-grade cars, ball bearings are used for the knuckle bearings as well as for the hub. Fig. 366 is an example of an axle end, which for real bearing worth, has probably never been surpassed; this is the axle end and steering knuckle of a very high-priced car, not now made, but one on which no expense was spared to make it perfect. The illustration shows the wheel hubs running on two very large diameter ball bearings, while the knuckle also turns on two very large ball bearings arranged for

radial loads. At the top is another ball bearing arranged for thrust; this bearing taking up all thrust loads from the weight above or from road inequalities. Fig. 367 illustrates the cup and cone type. This design utilizes ball bearings for the hubs and plain steel thrust washers on the knuckle.

## FRONT AXLE TROUBLES AND REPAIRS

**Alignment of Front Wheels Troublesome.** The lack of alignment of front wheels gives as much trouble as anything else in the

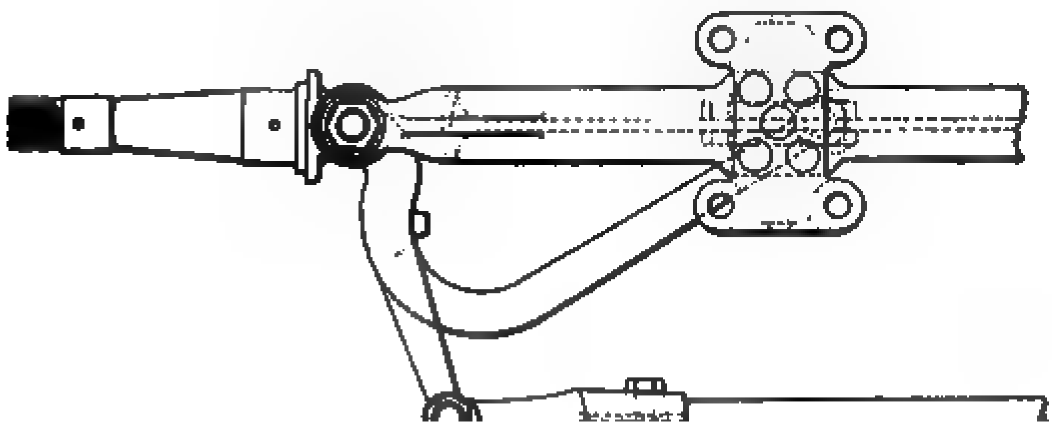


Fig. 367. Front Axle Details of Waverley Electric Car
*Courtesy of the Waverley Company, Indianapolis, Indiana*

front unit. This lack not only makes steering difficult, inaccurate and uncertain, but it also influences tire wear to a tremendous extent. As Fig. 368 indicates, even if the rear axle should be true with the frame, at right angles to the driving shaft, and correctly placed crosswise—correct in every particular with the shafts both straight so that the wheels must run true—the fronts may be out with respect to the frame, out of track with the rears, or out with respect to each other.

In order to know about the front wheels, they should be measured; while this sounds simple, it is anything but that. In the first

place there is little to measure from or with. A good starting place is the tires, and a simple measuring instrument is the one shown in Fig. 369. This instrument consists of a rod about ½ inch in diameter and about 3 feet long, fitted into a piece of pipe about 2 feet long, with a square outer end on each, and a set screw to hold the measurements as obtained. By placing this rod between the opposite sides of the front tires, it can be ascertained whether these are par-

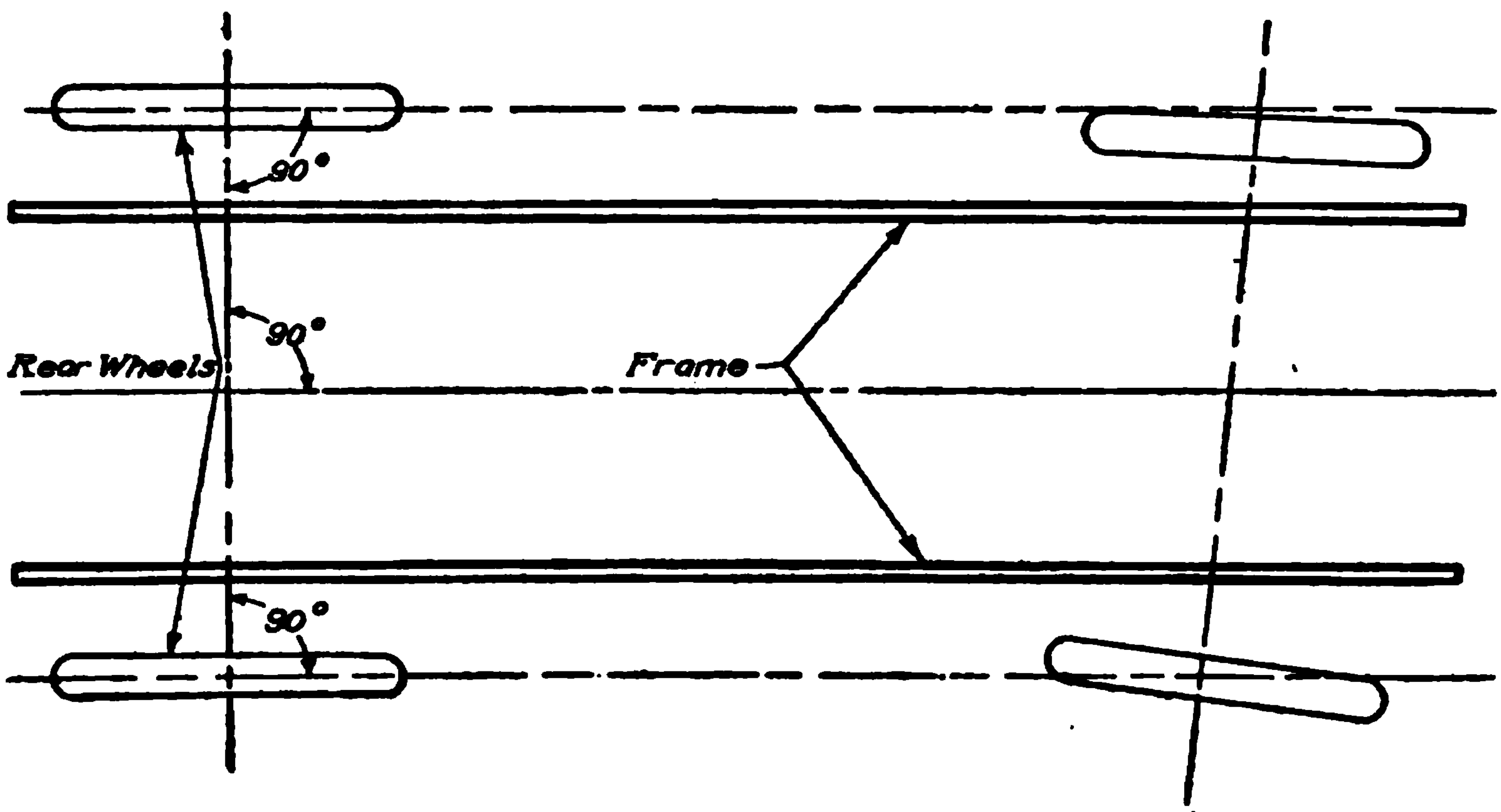



Fig. 368. Diagram Showing Front Axle and Wheels Out of True

allel, and whether they converge or diverge toward the front. But knowing this, the driver or repair man is little better off than before, because this may or may not be the practice of the makers of the car, and it may or may not cause the trouble.

In short, a more accurate and more thorough measuring instrument is needed, Fig. 370. Such an instrument can be bought, but a similar outfit can be made from ⅜-inch bar stock, using thumb nuts

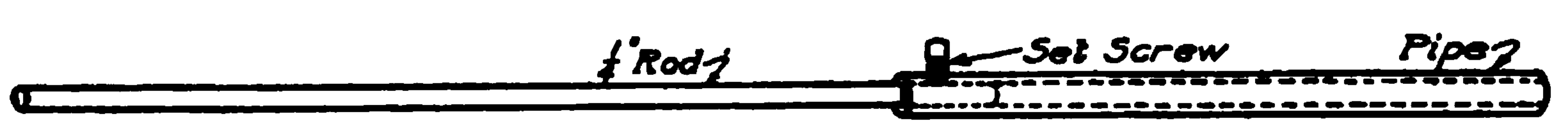



Fig. 369. Simple Measuring Rod for Truing-Up Wheels

where the two uprights join the base part, and also at the two points, or scribers, on these uprights. Having the floor to work from, the heights can be measured, and thus the distance between tires may be taken on equal levels. Thus, a bent steering knuckle can be detected with this apparatus. Similarly, the center line and frame lines of the car can be projected to the floor, and by means of the instrument, it can be determined whether the axle is at a perfect right angle

with the frame lines, and whether the wheels are perfectly parallel. Given the frame line, too, it can be determined whether the wheels track with one another.

**Straightening an Axle.** When an axle is bent, as in a collision, a template is useful in straightening it. This can be cut from a thin sheet of metal, light board, or heavy cardboard. It is an approx-

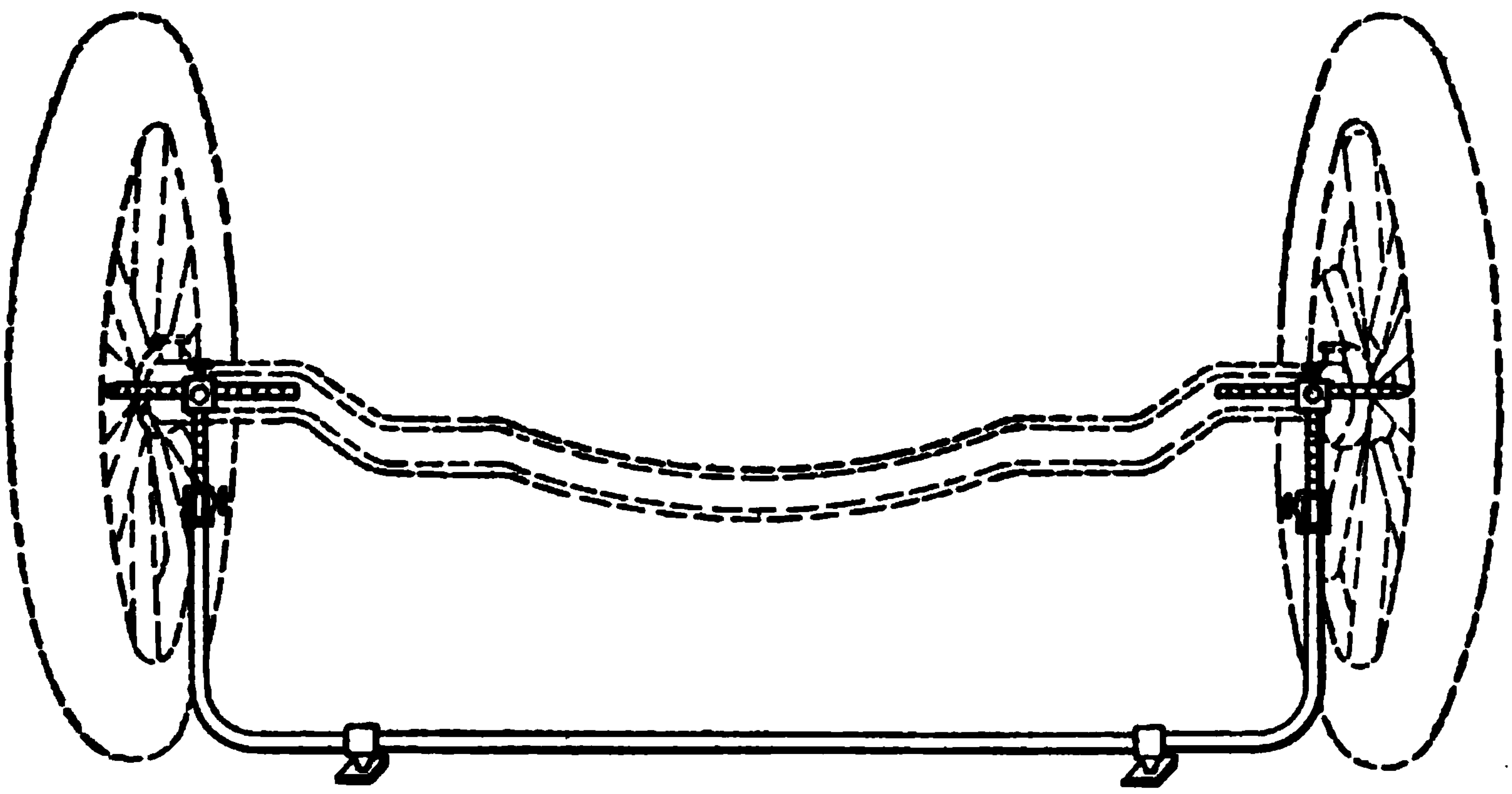


Fig. 370. Accurate Measuring Rod for Truing-Up Wheels. Better Design than Fig. 369

imation at best and should be used with great care. Fig. 371 shows such a template applied to an axle which needs straightening.

When the axle is bent back to its original position, a pair of straightedges laid on top of the spring pads will be of great assistance in getting the springs parallel, as the worker can look across the straightedges with considerable accuracy. This is indicated in the

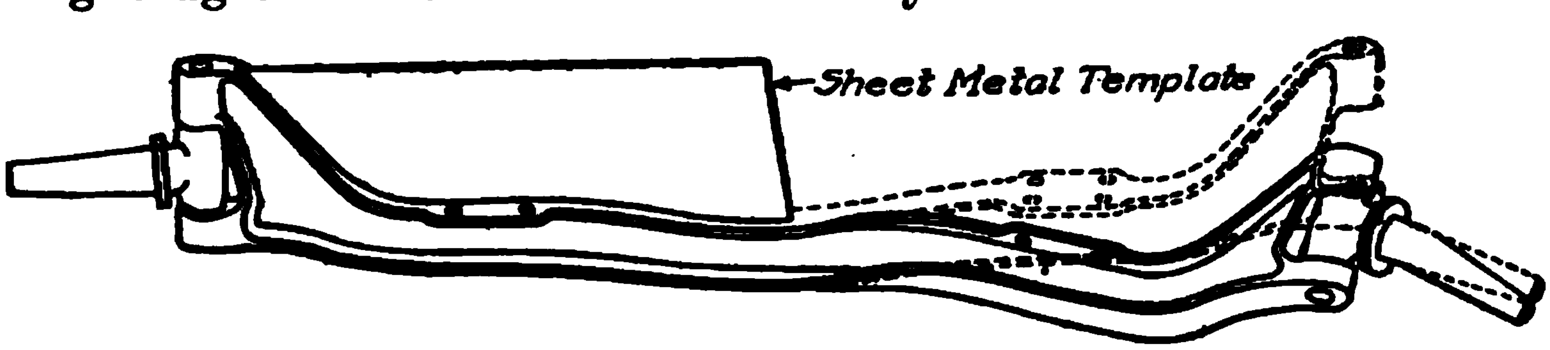



Fig. 371. Template for Showing if Axle Is Bent

first part of Fig. 372, which shows the general scheme. It shows also how the axle ends are aligned, using a large square on top of a parallel bar, but of course this cannot be done until the last thing, at least not until the spring pads are made parallel.

Front axles of light cars may be straightened without removal, provided the bend is not in the nature of a twist and not too short. Take two hardwood planks 7 feet long, 10 inches wide, and 2 inches

thick. Next, cut four ¾-inch blocks 10 inches long and 3 inches wide. Lay the blocks flat between the planks, space them about 2 feet apart, and bolt the whole securely. This obtains a girder 7 feet long, 10 inches wide, and 4¾ inches thick. Next, take two pieces of 4×4 timber 3 feet long and cut a tenon on one end of each. Make three ¾-inch eye bolts, 12 inches long, with nuts and plate washers for each. Place one of the eye bolts between each pair of blocks and screw up the nuts and washers sufficiently so as to rivet them. This permits of moving the eye bolts to any position between the blocks. Two small steamboat ratchets and several short but strong chains complete the equipment.

Fig. 372. Diagram Illustrating Method of Truing-Up an Axle

With an axle bent back in the center, lay the girder on blocks in front of the car so it will be level with the axle, place the tenons of the 4×4 timbers in the space between the planks of the girder, one on either side of the bend, and connect the axle to the girder by means of a chain, the ratchet, and the eye bolt. When the ratchet is tightened up, it draws the ends of the 4×4's against the axle on either side of the bend. Tightening the ratchet still further removes the bend. This work may be accomplished in 20 minutes or less or in about one-tenth the time it will require to displace the axle, heat it, and straighten on an anvil, etc. The apparatus can be used for straightening many different bends; all that is necessary is a different arrangement of its parts.

For example, a downward bend can be straightened by placing the car above the girder, connecting the axle to the girder, and using a short screw jack to remove the bend. This device can be used with success in shops dealing with light- or medium-weight cars.

**Spindle Troubles and Repairs.** Wear of the spindle, or knuckle bolt, and its bushings, as well as play in the steering-gear linkage, brings about wobbling of the front wheels when the car is in motion. Some experienced persons mistake wear of the knuckle and the bushings for play in the wheel bearings, and attempt to remedy the trouble by adjusting the bearings. It is a simple matter to determine the component at fault. To test for bearing play, drive a block of wood between the knuckle and the axle, then grasp the wheel at the top and

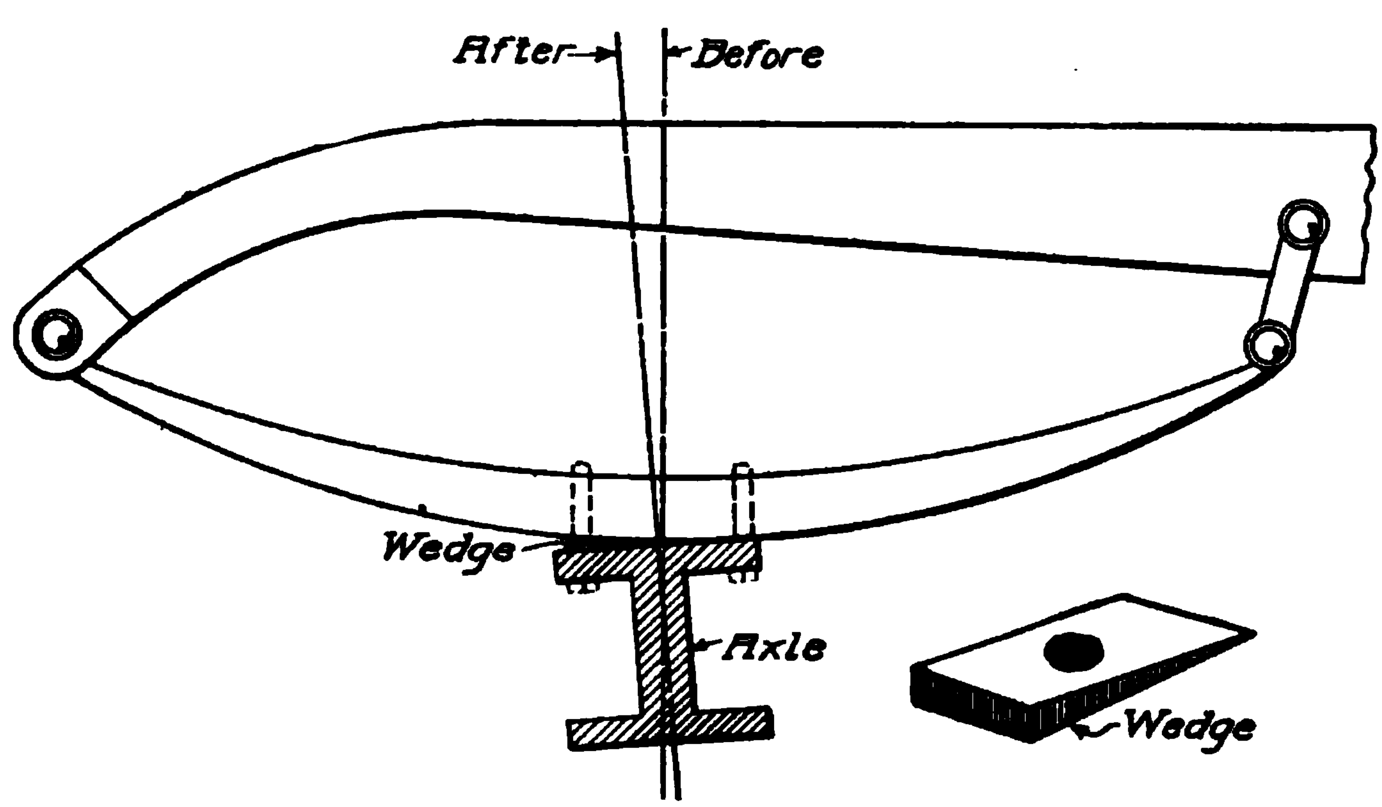



Fig. 373. Use of Wedge to Cure a Wobbling Wheel

bottom, or at points diametrically opposite, and test for looseness. If none exists, the play is in the knuckle pin and its bushings. The remedy is to fit new bushings and new knuckle pins.

**Wobbling Wheels.** Wobbling of the front road wheels is generally due to play in the joints of the steering mechanism, and it is not only troublesome, but also sets up undesirable stresses on the steering-gear linkage. This flapping of the wheels may be present with the steering gear and linkage in perfect operating condition, and similarly when the springs, hangers, etc., are in good condition and the proper toe in, or gather, of the wheels exist.

When the wheels wobble it may be assumed that the front springs have so settled that the steering pivots are not quite vertical fore and

aft, particularly with reference to that type of pivots which do not incline outwards and where the wheels are canted or dished to bring their points of ground contact in line with the pivots. A cure for this trouble is to place wedges between the front springs and spring seats so as to alter the angle of the steering pivots, as shown in Fig. 373. Metal wedges are used, about $\frac{1}{8}$ inch thick at the large end, and tapered to a knife-like edge. The wedge is placed at the forward end of the axle, and a little experimentation will give the results desired. In wedging, as few wedges should be used as is necessary to obtain the desired result.

## CHASSIS GROUP

In arranging a logical presentation of the numerous components of the motor vehicle, the chassis is separated from the body. It includes the power plant and mechanism utilized in transmitting the energy of the engine to the road wheels, also the frame and suspension, the axles, etc. However, only frames, springs, and shock absorbers will be discussed in this section, as the other parts of the chassis have been treated.

**Characteristics of Parts.** *Frames.* The chassis frame practically is the foundation of a motor vehicle, since all of the power transmitting and other units are attached to it. Motor-vehicle construction depends, to a certain extent, upon the general design of the chassis, the construction of the power plant and transmitting units, their mounting, the method of final drive, the wheelbase, etc. The size of the material used depends upon the weight of the units carried and the capacity of the vehicle, and varies from thin and small sizes on very light pleasure cars to heavy structural I-beam frames on commercial vehicles.

The use of pressed steel is becoming more popular, as is also the tendency to narrow the frame at the front to obtain a shorter turning radius. The majority of designers favor what is termed a kick-up at the rear, which affords better spring action and permits of a low suspension of the body. The use of tubing and wood has practically been abandoned. There is a slight return to favor of the underslung suspension, a form that was popular several years ago but which did not then obtain the results claimed for it, as the springing gave some trouble.

*Springs.* The primary function of the spring is to absorb the road shocks that would otherwise be communicated to the mechanism and passengers. Considerable progress has been made in the past year toward improving springs, and not only are they better proportioned, but improved material and methods of mounting have, to a great extent, eliminated breakage. The leaf type, developed by the horse-drawn carriage industry, is the form universally employed on motor vehicles, both pleasure and commercial.

A review of the 1916 springs for cars showed that the three-quarter and seven-eighths elliptic spring was favored by 46.5 per cent of the makers, while some form of cantilever spring was second with 28.7 per cent for rear suspension. This year the advocates of the cantilever have gained many new recruits. In the matter of front springs, the semi-elliptic may be said to practically monopolize the field. The coil spring is a thing of the past.

*Shock Absorbers.* The fitting of shock absorbers as standard equipment is not as noticeable as it was in 1916 and the year previous. The use of high-speed engines with light reciprocating parts, and the employment of high-grade light material in other components of the chassis, together with better springs, serves to absorb shocks created by traversing rough roads. A few makers supply shock absorbers, but, as a rule, the car manufacturer leaves the selection to the purchaser. Many different types of shock absorbers are marketed, and use is made of varying principles.

## FRAMES

**General Characteristics.** When the automobile was first introduced, comparatively little attention was paid to the frame, as the other components of the chassis, such as the power plant, gearset, axles, etc., were held to be of greater importance, consequently the frame did not receive the consideration it should. After experiencing considerable difficulty, however, due to accidents and other failures which were traced directly to poor frame design, the automobile engineer found that it was possible to build a frame of great strength with less weight than the troublesome types. This statement applies to the frame of the commercial car as well.

The improvement in frame design is the result of the tendency to provide perfect alignment of the power plant, clutch, and gearset,

making use of what is known as the unit power plant on some models, while on others, particularly of the heavier type, flexible mounting of the units has been resorted to. The tendency is toward the use of a flexible mounting of all individual units, at least to some degree, in order to relieve them of the stresses brought about by frame weaving when the road wheels mount an obstacle on the road surface.

**Classes of Frames.** The most prominent types of frames, divided according to their use, are the pressed-steel frame, the structural frame, and the structural I-beam frame; the latter is confined to commercial cars. These classes may be subdivided according to the general construction and material, as well as to the distribution of the chassis units.

The material employed is either pressed or rolled steel. The wood frame or combinations of wood and metal frames are practically a thing of the past, and are to be found, with one or two exceptions, on old cars. The steel frame may be constructed in the following shapes: channel, L-beam, angle, T, Z, tubing, flat plates, and combinations of any two or more of these. Other forms are possible. For example, the channel may be turned with the open side in or out, the two constructions being widely different; or the angle may have the corner down and out, down and in, up and out, or up and in. Similarly, the T-shape may be a solid T turned up or down, or it may be a hollow T-section with space between what might be called the two sides of the leg; this shape may be turned either up or down, while the Z-shape may be turned horizontally or vertically. Many frames are constructed with the open end of the channel section turned in, and use is made of a steel underpan of flat section attached to the under side of the main frame. In several instances there is a tendency to make the frame and underpan as one piece, in which case the frame section assumes the shape of a channel with an exceedingly long lower flange.

Another type of frame is that having a continuous section throughout. Others have a varying section. Thus, the ordinary steel frame of modified channel section may have a depth of perhaps 5 inches at the center, a width of upper flange of $1\frac{1}{4}$ inches, and a width of lower flange of 2 inches. A frame similar to this would taper down to the ends to perhaps 20 inches in vertical height, and to 1 inch in width of both top and bottom flanges. Then, again, frames which are

bent upward or downward at the ends or in the middle really differ from those frames which preserve one level from end to end. The practice of bending the chassis frame is very prevalent of late, the upturning of the ends bringing about a lower center of gravity, making for stability and ease of entrance and exit to the body.

**Tendency in Design.** There is a marked tendency toward making the chassis frame wider at the rear and narrower at the front. In one or two cases the designer appears to have gone to the extreme in this respect. The advantage of the narrow front construction is that it enables the car to be turned in a shorter radius. The use of a wide rear frame provides more space to support a wider body. A more recent development is to make the longitudinal bars of the frame parallel over the front spring and near the rear spring, and to have them tapered from behind the front to the rear springs. A certain amount of material is said to be gained by this construction, as no heavy reinforcement or sudden offset is necessary to the frame. By

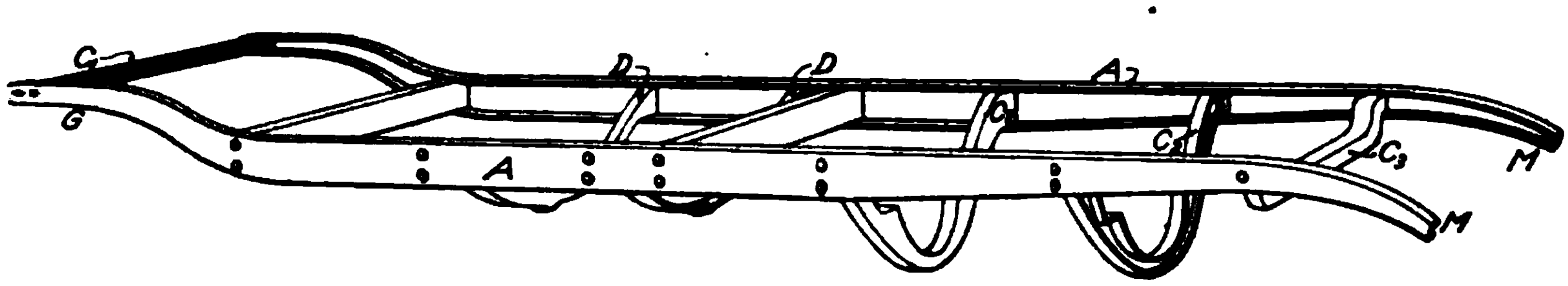



**Fig. 374. Typical Automobile Frame of Pressed Steel**

widening the frame at the rear it makes possible the placing of the springs directly underneath the frame. Some car makers have the sides of the frame straight over the entire length, but tapered from the front to the rear.

Fig. 374 illustrates what is termed a single drop or a kick-up. This is a type of pressed-steel construction, of channel section, and the deepest and strongest section is at the center where the greatest stresses occur. Some frames are built with a double drop, having a downward bend just forward of the entrance to the rear part of the car body, followed by an upward turn just back of the same entrance. The upward turn at the back is carried higher than the main part of the frame for the purpose of obtaining a low center of gravity. Then there is what is termed the bottle-neck construction, a bend inward which resembles that in the neck of a bottle. This obtains a short turning radius. Originally, frames were narrowed in front, the difference in the width between the front and rear being at first an inch

or so on each side, gradually increasing until it became 5 and 6 inches. This type did not prove efficient, and the trend favored the taper previously explained.

A not uncommon form of frame is shown in Fig. 375, which compensates for an abnormal rise of the rear axle without the possibility of its striking the frame. Some frames have a bend at the ends to take the spring fastenings.

**Pressed-Steel Frames.** The pressed-steel type of frame is very popular with designers and is largely used on commercial cars up to and including 1-ton capacity. This is popular because it is the lightest in weight for equal strength of the structural iron or rolled channel and I-beam section. The cost of pressed steel is somewhat higher,

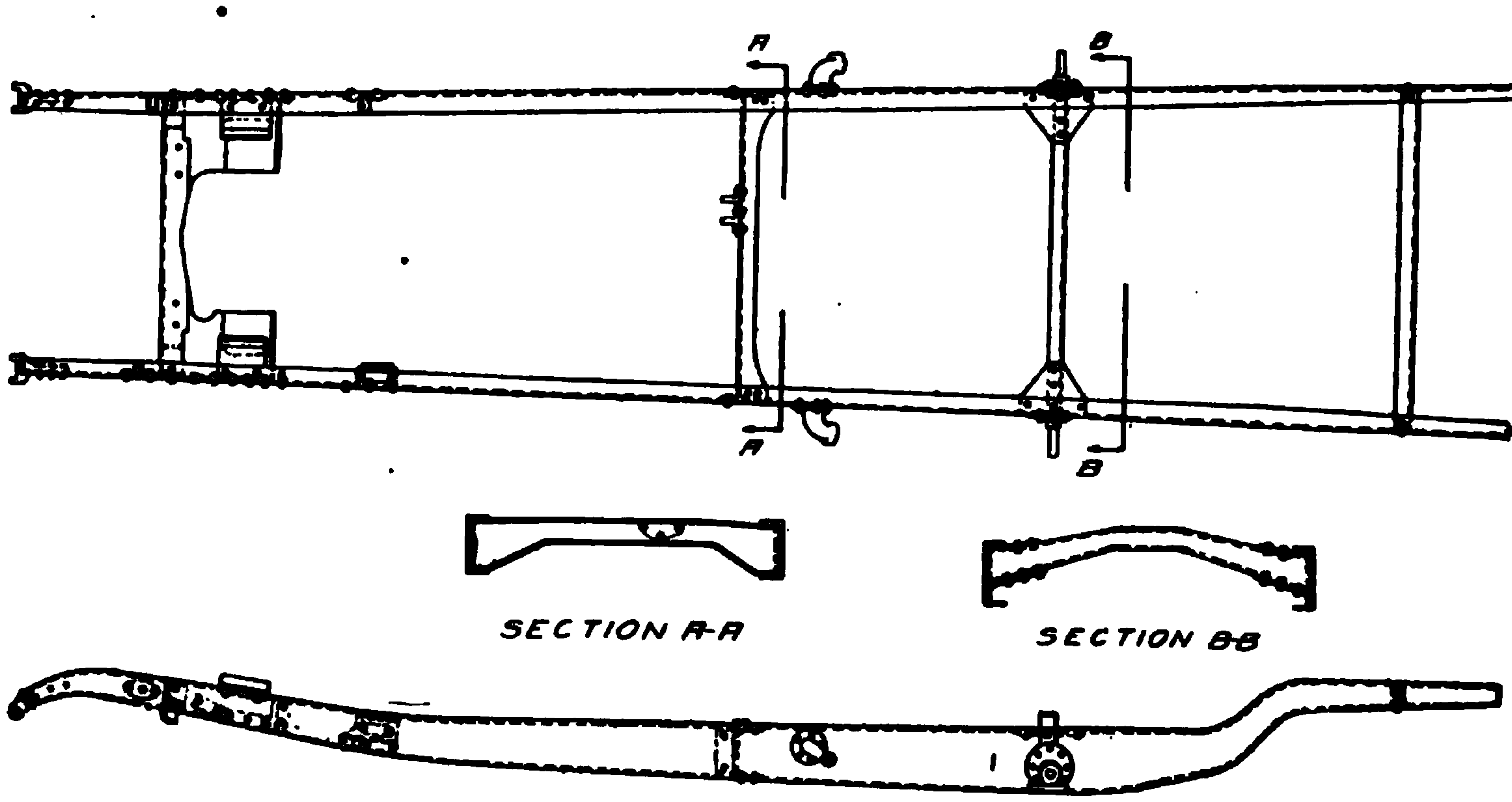



Fig. 375. Frame of Sterns-Knight Car in Plan

because it is heat-treated material used to obtain maximum strength. The cost varies with the section, material, and the nature and extent of bending. The finished frames are easy to handle, and the assembling cost is small. The channel shape is easy to brace and repair. These and other advantages have brought about its use.

The cheapest construction is the straight side rail, and, when conditions permit, it is usually tapered at front and the rear, and the forward end is sometimes shaped to receive the spring hangers. When the side members are inswept to permit a short turning radius, it is necessary to make the flanges of the side rail of considerable width at this point, tapering gradually to the rear, to provide the proper strength at the point of offset.

**Sub-Frames.** The modern tendency is to eliminate the sub-frame—a step due to the flexible mounting of the power plant and unit construction—because it simplifies the frame. It has also been made easier by the tapered frame, which is narrowest at the front where the units are attached. The most common method of supporting the engine is the three-point. Sub-frames are used, however, as they serve the purpose both of supporting some unit and of strengthening the frame.

Sub-frames may be of two kinds, viz, those in which the sub-frame is made different for each unit to be supported, and others in which one sub-frame supports all units regardless of size, shape, or character of work. The type of sub-frame made to support each unit usually works out to two pairs of cross-members, one for the front of the unit and one for the rear; while the type which supports all units regardless of size works out to longitudinal members, supported, in turn, by two cross-members, front and rear. The added weight for the first-mentioned type is less than for the other, since it comprises only four cross-members; while the last-named type consists of two cross-members equal to two of the others and of two very long members parallel to the main-frame members, each much longer and thus much heavier than the corresponding cross-members. In the two frames already shown, Fig. 374 shows the unit type of sub-frame with only cross-members, while Fig. 375 shows the more modern type in which the power plant is of the unit type and rests directly upon the main frame, being the three-point suspension type in which the forward point is on a frame or special cross-member, while the rear two points are the crankcase supporting arms resting directly on the main frame.

**Rigid Frame.** A pressed-steel or rolled-stock rigid frame has its advantages, particularly with reference to the commercial vehicle. It permits the body to be rigidly secured to it, and as it does not give with the inequalities of the road, the body is not racked. An advantage of the rolled stock is its cheapness, except, of course, for the lighter models of the assembled type for which frames can be secured at low figures. Another advantage of the rolled stock is the ease with which the wheel base may be altered.

**Effect on Springs.** The effect of frame construction upon the design and duty of springs should be considered. This feature

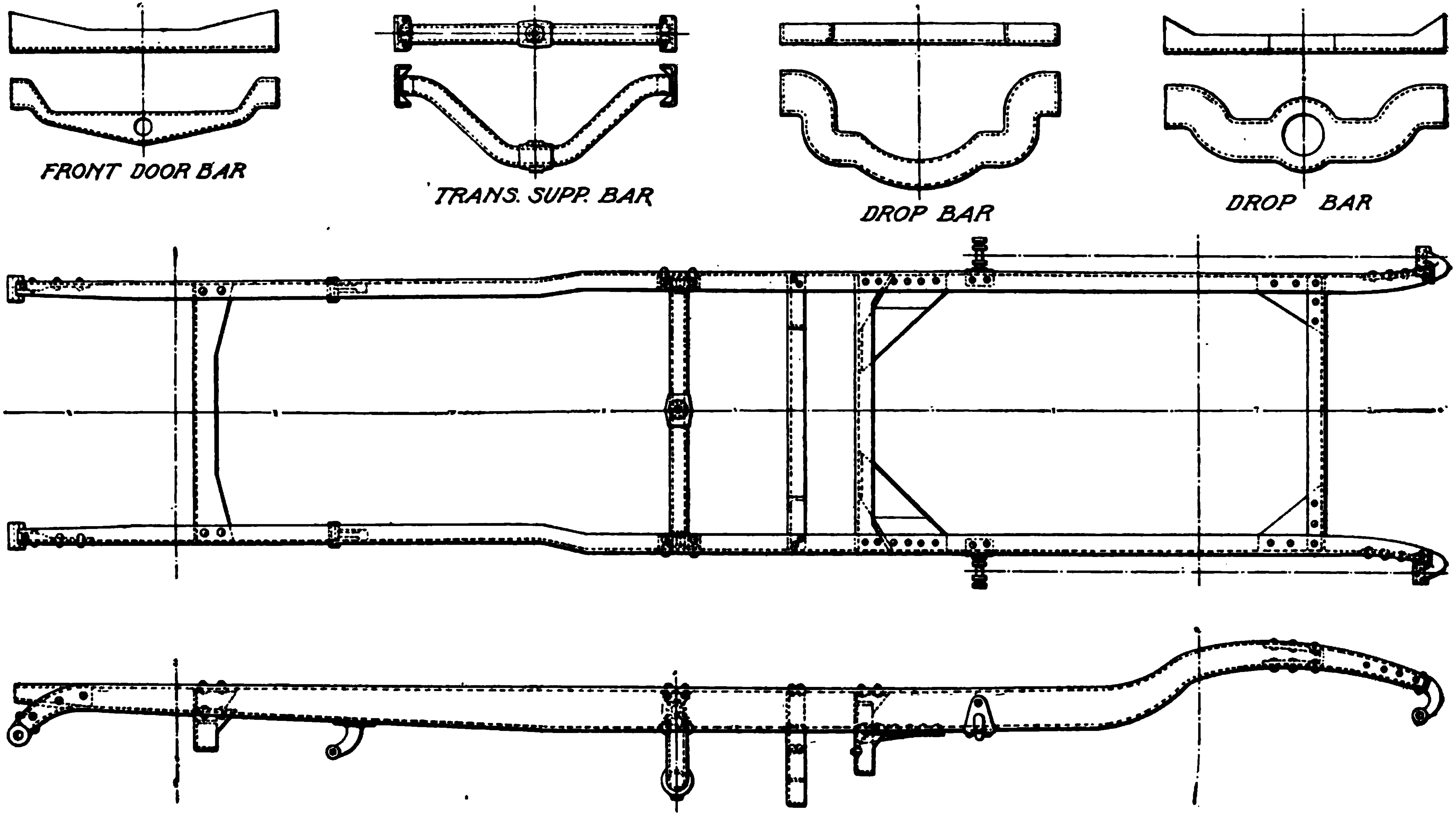



Fig. 376. Plan, Elevation, and Sectional Details for Chassis Frame with Narrowed Front
*Courtesy of A. O. Smith Company, Milwaukee, Wisconsin*

is not generally understood, but it has an important bearing upon the life of the car. A rigid frame relies upon the springs to allow for all axle displacement. If a front and a rear wheel on opposite sides are raised several inches at the same time, the frame is subjected to a torsional stress. If the frame is rigid, springs of considerable camber must be employed in order to absorb the shock without being bent past the limit of safety, and they must be sufficiently flexible to absorb all the shock without any tendency to lift the other wheels from the ground. To accomplish this shock absorption, a different type of spring is used on a rigid chassis from that employed on a flexible frame. The use of underslung spring suspension has come into favor for this reason, as it permits the frame to be carried fairly low, without sacrificing spring camber or necessitating a dropped rear axle.

The flexible frame, when diagonally opposed wheels are raised, does not impose all the stresses on the springs but it absorbs a part of them. For this reason, springs on a flexible chassis are flat or nearly so, with a limited amount of play. Flexible construction also permits the frame to be carried equally as low as with the underslung spring, and yet the spring is perched above the axle, where it is more nearly in line with the center of gravity, thus reducing side sway.

## TYPES OF FRAMES

**Pressed Steel.** Pressed steel is purchased in sheet form, cut to the proper shape in the flat, and then pressed into channel form under great pressure. It is made of steel rolled into sheets and is somewhat closer grained than ordinary steel. There is no breaking of the flake in the rolling process. The pressed-steel frame, as previously pointed out, permits of greater simplicity in assembling, since the parts can be easily bolted or riveted. Fig. 376 is of the type of pressed-steel frame having a tapering section, a kick-up at the rear end, five cross-members —one of them a tube—and is narrowed in at the front to give the largest steering lock. Otherwise it presents only standard practice.

**Wood.** Wood is universal and easy to obtain. While no longer classed as cheap, it is not expensive; moreover, wood is kept in stock nearly everywhere. Users of wood for side-frame members claim that the wood frame is not only lighter but stronger. In addition, the wood frame would undoubtedly possess more natural spring and

**TABLE IV**

**Comparative Strength of Steel Channels and Laminated Wood Frames**

| Material | Size (in.) | Weight per Linear Inch (lb.) | Resisting Moment | Resisting Moment per Unit Weight |
|---|---|---|---|---|
| Pressed Steel | $\frac{3}{16} \times 4\frac{5}{8} \times 1\frac{3}{4}$ | .408 | 114,830 | 280,955 |
| Ash | $1\frac{3}{4} \times 6$ | .266 | 142,275 | 534,870 |

resiliency, so that it would make a lighter and easier riding frame. A section of a wood frame is shown in Fig. 377.

This shows a frame made of laminated wood. There are three very thin sections of selected ash, marked *A*, which are glued together, then screwed and bolted to prevent the glue from opening up. To further this purpose, a strip *B* is fastened on the top and bottom in the same manner. These strips are laid with the grain running horizontally; while the main pieces are laid with the grain running vertically. This construction makes a very strong and light-weight frame; the comparative figures for a steel section and the section shown, as given from the tests of the engineers of the Franklin Company, is shown in Table IV. These tests, which are authentic, seem to bear out the contention that the wood frame is both lighter and stronger than the steel frame.

Fig. 377. Section through Wood Side-Frame of Franklin Car

**Novelty of Fergus Frame.** A new American car, the Fergus, shows more novelty in frame construction, as well as in every other conceivable way, than any other. Instead of blindly following accepted practice in the matter of frame design and construction, the makers have struck out boldly along new lines.

The Fergus car was developed as a result of fifteen years' experience in fine repair work, and is an attempt to eliminate the usual "owner troubles". While not intended as a "foolproof" car, the Fergus comes nearer being one than any other developed up to this time. In addition to actually "fool-proofing" the car, the aim of the makers was to eliminate much of the work incident to caring for the modern car by replacing the usual "owner-attention" with an automatic system.

In the frame, a combination of steel girder and lattice work has been produced which has the appearance of being absurdly light. However, as the diagram of stresses in its members, Fig. 378, indicates, everything has been figured out with the utmost care, and the design has been supplemented by unusual workmanship.

The complete frame, Figs. 379 and 380, shows that a large part of the saving is produced by the method of suspending the units. Were these hung on the side members, as in the ordinary case, the frame certainly would not do, but as it is, they are hung on immensely strong brackets, steadied by the side members, but rigidly supported by large tubular cross-members. The brackets and cross-members do the work ordinarily assigned to the side members of the frame, the side members simply joining and holding together the various brackets and cross-members.

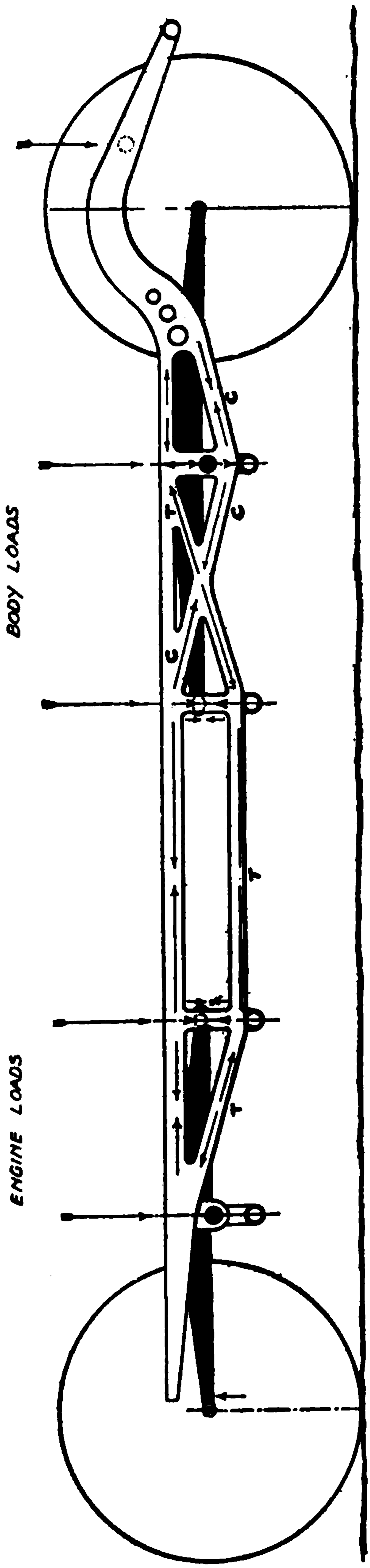



Fig. 378. Diagram of Fergus Trussed Frame, Showing Light but Strong Construction

An examination of the design reveals the astonishing extent to which the brackets have been combined, the rear engine member, for instance, also acts as the rear support for the front spring, for

Fig. 379 Forward Portion of Chassis of Fergus Car, Showing Method of Attaching Springs, Front Axle, and Engine

the step support, and for the dash support. At the sides and rear there is a similar combination of functions.

**Recent Types of Frames.** An innovation in frame design is the Marmon, shown in Fig. 381, the side rails and running boards of which are made in a single unit. The great width of the running board,

Fig. 380. Rear Portion of Chassis of Fergus Car, Showing Simple Spring and Rear-Axle Construction

varying from 11½ to 16 inches, serves as the bottom flange of the frame, and is therefore of Z-section. The vertical section of the frame is 10 inches high, and has height enough to replace the running board fenders without appearing narrow. At the front and rear ends of the frame, the running boards are curved upward, strengthening the frame

Fig. 381. Marmon Aluminum Frame, Showing Running Board Construction

as well as supporting the fenders into which they merge. The frame, beyond these points, both forward and rearward, is made of channel section of the conventional type. The rear of the frame is 45 inches wide and tapers to 30 inches at the front spring hangers. The great depth of the frame section makes it very stiff, so that the body sills

Fig. 382 Brush Pressed-Steel Frame
*Courtesy of Hale and Kilburn Company, Philadelphia, Pennsylvania*

can be entirely eliminated, and yet the doors will not work loose or bind when the top is up or down.

Fig. 382 illustrates a type of frame similar to the Marmon, the Brush frame, controlled by the Hale and Kilburn Company, of Philadelphia.

*Steel Underpans.* The underpan has assumed a great deal of importance in the last two years, for makers have more and more realized that it is highly important to protect many of the parts from road dirt, flying stones, water, etc. Designers have, therefore, given

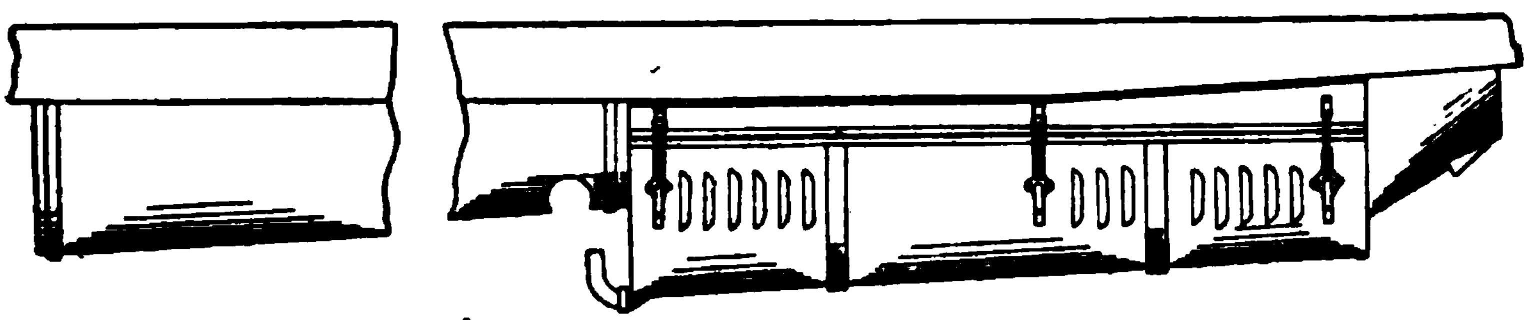


Fig. 383. Two-Piece Pressed-Steel Underpan Used on Winton Cars
*Courtesy of Winton Motor Car Company, Cleveland, Ohio*

considerable attention to its shape, size, and method of attachment. In some types, it apparently runs underneath both engine and transmission and is made more or less a part of the main frame. Therefore, its quick removal on the road would be difficult, if not impossible; yet road accidents sometimes make it necessary for the driver to take this pan off to get at the lower side of engine, clutch, or gear box.

For this reason, underpans generally resemble more closely that shown in Fig. 383. This is a side view, showing the semicircular form of the pans, as well as the two-piece construction. The forward part under the engine, which would be taken down fairly often, is held in place by three spring clips on either side. Lifting these clips off is only a second's work; in addition, there is a filler piece in front, helping to make the pan fairly air-tight. The depth of the pan increases slightly toward the rear, so as to form a slope down which liquids will drain; the rear end is fitted with an upturned elbow, so that it will not drip until it accumulates a considerable quantity of liquid. Continual dripping indicates a full charge, and the pan is drained by turning the elbow over.

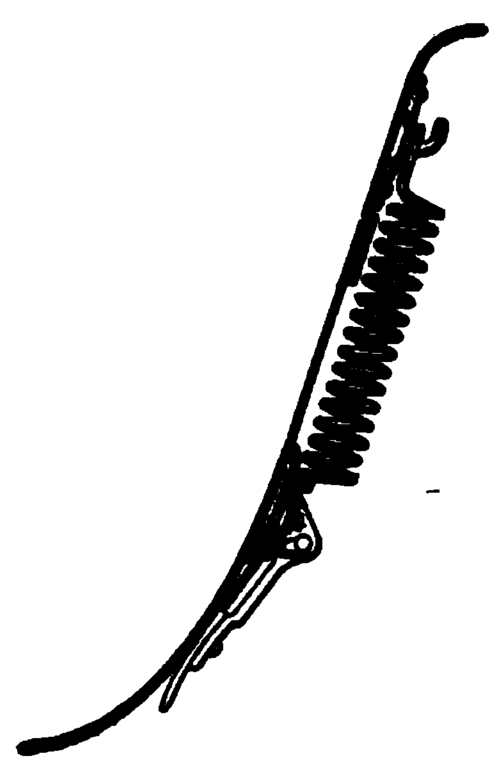


Fig. 384. Detail of Spring and Section of Winton Underpan

In Fig. 384, a detail of the arrangement of the pan shown in Fig. 383 is presented. This indicates both the permanent part of the underpan, which is attached to the frame, and the removable part, which is freed by loosening the spring clips shown.

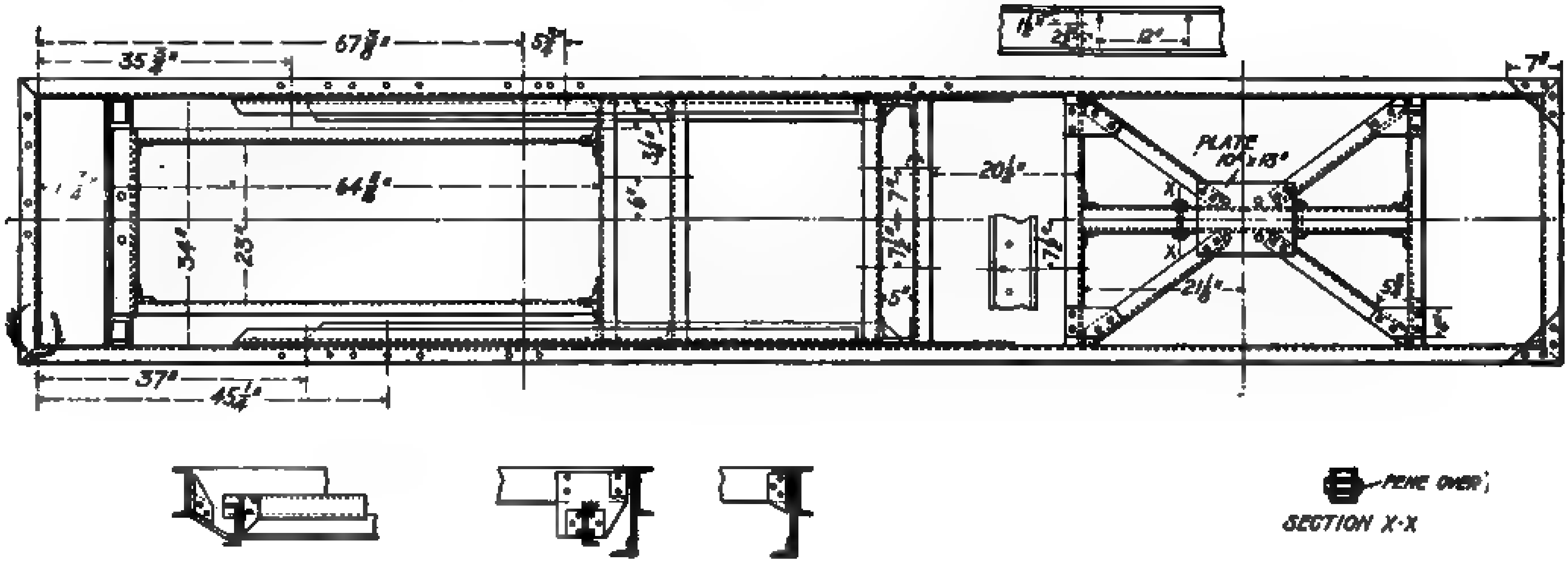



Fig 385. Plan and Elevation of Frame of Heavy Truck

**Commercial-Vehicle Construction.** Commercial work, being rougher, harder, and cheaper work, changes the frame construction just as it does everything else about the car. In Fig. 385, a commercial-vehicle frame which brings out this point is shown. The main sills are 6-inch channels, while all of the other members are correspondingly large angles and channels. In one place the section consists of a box shape made up by bolting two large channels together, with the open sides in. The total overall length is not given, since this differs according to the variations in the wheel base; but, by a comparison of the figures given, it is seen that the frame shown is in

Fig. 386. Solid Rear Construction of Locomobile for Tires and Tanks
*Courtesy of Locomobile Company of America, Bridgeport, Connecticut*

excess of 210 inches long by about 37 inches outside width. This is about twice the total length of the average small car.

In the bracing and arrangement of the different members, this frame shows other points of difference, the cross-members, for instance, being nine in number, not including the two diagonal cross-members. The longitudinal members, too, are eight in number, not counting the two diagonals.

**Rear-End Changes.** The locating of the fuel tank at the rear of the chassis—a practice that was brought into favor largely through the introduction of the vacuum system of fuel supply—has resulted in a number of changes to the rear ends of frames. The placing of the fuel tank at the rear is not new, and probably it would not have

occasioned any change to the rear end of the frame were it not largely for the fact that the spare tires are now carried at the rear of the chassis. The tires themselves are not heavy enough to make it

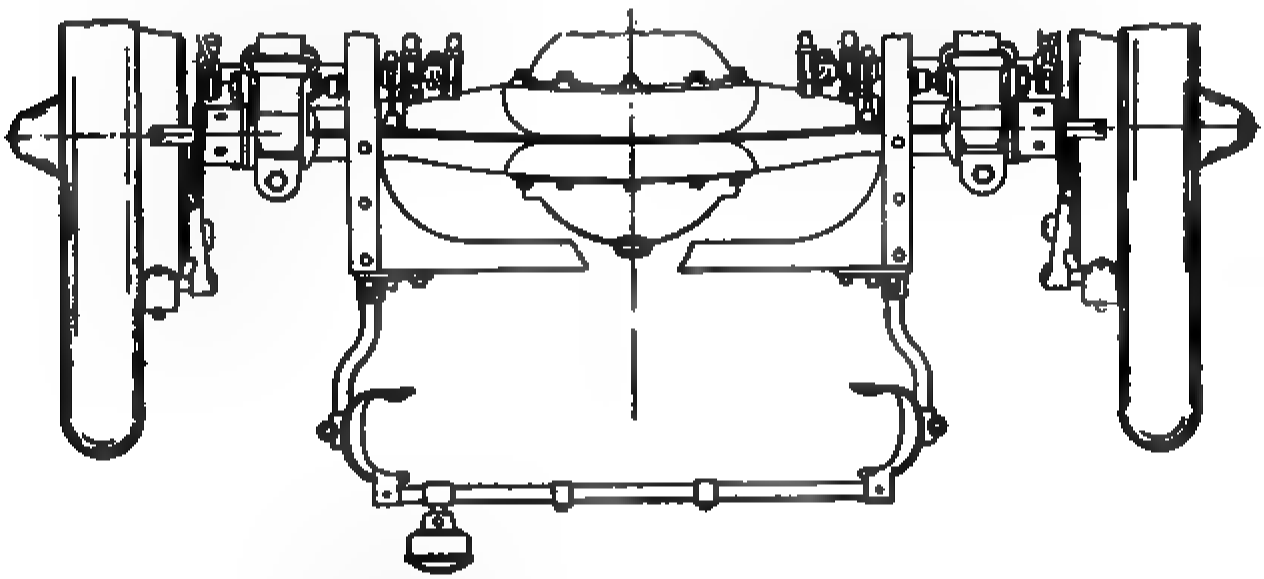


Fig. 387. Sketch of Rear-End Construction of Reo Car

essential to strengthen the rear ends, but the very general use of carrying the spares inflated on demountable rims has added considerable weight to the rear of the chassis. This weight, coupled with

Fig. 388. Typical Rear-End Construction, Carrying Gasoline Tank

that of a large fuel tank, has compelled makers to give more attention to the rear construction.

Provision is made for carrying the spare tires on the Locomobile chassis by means of an apron conforming in shape to the shoe. The three-quarter elliptic springs of the scroll type have ends attached to the outside of the main frame, which is carried back and serves as an

extension for attaching the fuel tank. A cross-member is also utilized; it serves as a point of attachment for the two rods supporting the lower apron and for two upper rods as well. This design has merits in that the tire carrier is firmly anchored and serves to protect the fuel tank from injury possible in operating in crowding traffic where rear-end collisions are not uncommon. As may be noted, Fig. 386 shows the method of using an upper cross-member to prevent theft of the tires.

A different type of rear construction is shown in Fig. 387, a Reo. Here the rear cross-member is gusseted, and a pair of substantial arms are riveted to the cross-member. These arms serve as an anchorage for the tire holders which, in turn, have a cross-rod for protection. Still another design is shown in Fig. 388. Here the side rail of the frame projects back of the rear cross-member of the frame for a distance of about 12 inches. The fuel tank is suspended from these two extended frame members by means of steel straps which pass around the tank.

## FRAME TROUBLES AND REPAIRS

The more usual troubles which the repair man will encounter are sagging in the middle; fracture in the middle at some heavily loaded point or at some unusually large hole or series of holes; twisting or other distortion due to accidents; bending or fracture of a sub-frame or cross-member; bending or fracture at a point where the frame is turned sharply inward, outward, upward, or downward.

**Sagging.** A frame sags in the middle for one of two reasons, either the original frame was not strong enough to sustain the load or the frame was strong enough normally, but an abnormal load was carried, which broke it down. Sometimes a frame which was large enough originally and which has not been overloaded will fail through crystallization or, in more common terms, fatigue of the steel. This occurs so seldom, and then only on very old frames, that it cannot be classed as a "usual" trouble; moreover, it cannot be fixed.

When a frame sags in the middle, the amount of the sag determines the method of repair. For a moderate sag, say $\frac{1}{4}$ to $\frac{1}{2}$ inch, a good plan is to add truss rods, one on either side. These should be stout bars, well anchored near the ends of the frame and at points

where the frame has not been weakened by excessive drilling. They should be given a flattened U-shape, with two (or more) uprights down from the frame between them. The material for them should be stiff enough and strong enough to withstand bending and should be firmly fastened to the under side of the frame. The truss rods should be made in two parts with a turnbuckle to unite them, the ends being threaded right and left to receive the turnbuckle. When truss rods are put on a sagged frame, it should be turned over and loaded on the under side; then the turnbuckles should be pulled up so as to force the middle or sagged part upward a fraction of an inch, say $\frac{1}{8}$ to $\frac{1}{4}$ inch, and then the frame turned back, the other parts added, and the whole returned to use. A job of this kind which takes out the sag so that it does not recur is a job to be proud of.

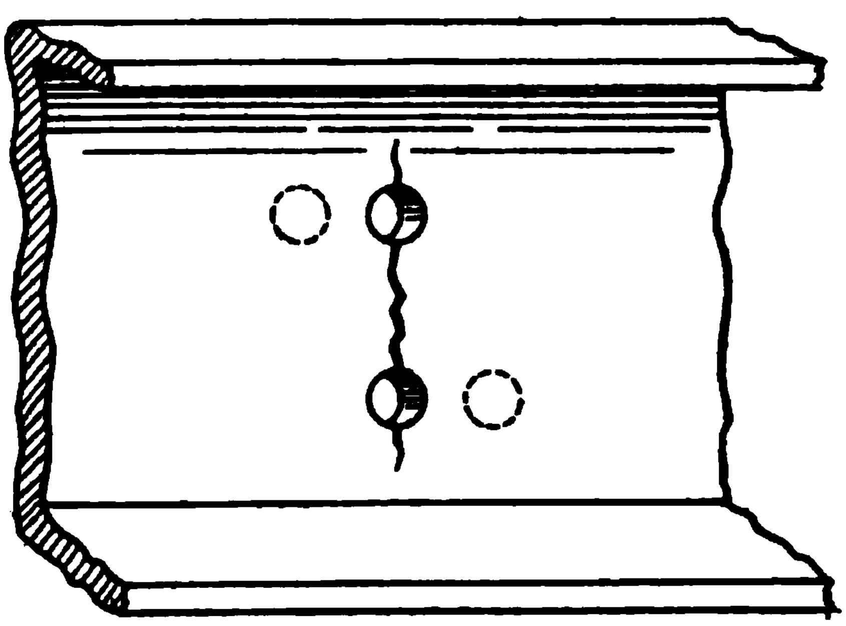


Fig. 389. Reboring Cracked Steel Channel

**Fracture.** Many frames break because too much metal was drilled out at one place. Fig. 389 shows a case of this kind. The two holes were drilled, one above the other, for the attachment of some part, and were made too large. They were so large that at this particular point there was not enough metal left to carry the load, and the frame broke, as indicated, between the two holes and also above and below. A break of this kind can be repaired in two good ways. The first and simplest, as well as the least expensive, is to take a piece of frame 10 to 12 inches long, of sufficiently small section to fit tightly inside this one. Drive it into the inside of the main frame at the break, rivet it in place firmly throughout its length, and then drill the desired holes through both thicknesses of metal.

This is not as good as welding. A break of this kind can be taken to a good autogenous welder who will widen out and clean the crack, fill it full of new metal, fuse that into intimate contact with the surrounding metal, and do so neat and clean a piece of work that one would never know it had been broken. When a welding job is done on a break like this, and no metal added besides that needed to fill the

crack, subsequent drilling should be at an angle, to avoid a repetition of the overloading condition. In the figure, the dotted lines suggest the drilling. By staggering the holes in this way, there is a greater amount of metal to resist breakage than would be the case with one hole above the other—a method which might preferably have been used in the first place.

So much welding is done now, and so many people know of its advantages, that every repair shop of any size should have a welding outfit. A frame job is essentially an inside bench job, but a large number of cases of welding could be done directly on the car outside the building, particularly in summer when the outside air and cooling breezes are desirable. So, it is well to construct a small truck on which to keep the oxygen tank, acetylene cylinder, nozzle for working, and a fire extinguisher. One form of a truck is shown in Fig. 390. This truck is a simple rectangular platform with casters, a handle, and a rack to hold the tanks. It saves many steps and is particularly convenient in summer months. This outfit is essentially a home-made affair, but the gas-welding and electric-welding manufacturing companies have designed small outfits especially for automobile repair work, which would be preferable to the one in Fig. 390, especially where the amount of repair work warrants a reasonable expenditure for a welding outfit. A description of both gas and electric outfits and instructions for their use are given in the section on Welding for Automobile Repair Work.

Fig. 390. Handy Oxy-Acetylene Outfit

**Riveting Frames.** *Tightening Rivets.* Rivets securing the corners of a frame or holding cross-members, gussets, and plates often work loose, particularly with the flexible type of frame previously alluded to. The location of the rivet and the accessibility of the part will determine how best to proceed with the work. The chief trouble experienced is that of placing a sufficiently solid article against the rivet

while the other end is being hammered. As a rule, old axles, sledges, and hammers will serve under ordinary conditions, but these cannot always be used in a channel frame. One method is to employ an old anvil which is turned upside down and so placed in the frame that the flat end of the anvil is placed against the head of the rivet, while a rivet set is employed to set the rivet up snug. The horn of the anvil is allowed to rest on the other side of the frame. This method can be used for cutting off rivets as well as for tightening old ones. The anvil should be of sufficient length to rest on the frame as above described.

When an anvil is not available, the following method may be used with success. Take a ½-inch bolt and cut it off so that it will just go in the frame between the rivets. Slightly countersink the head of the bolt with a cold chisel. Put on the nut and slip in between the rivets and run the nut down until it expands tight in the frame. The depression in the head of the bolt, and the nut fitting around the opposite rivet head will keep it firmly in place while riveting. It is not always practical to attempt to tighten a rivet. The better method is to remove it, drill a larger hole and use a larger size rivet. Rivets are usually made of Norway iron. Heat to a red heat before using.

Fig. 391. Method of Riveting Frame

*Riveting Methods.* There are two methods of riveting, the driving in and the backing in. The latter method is shown in Fig. 391, and the two plates to be riveted are drilled in the usual manner, as shown at *A*, with the rivets a trifle smaller than the hole, placed as shown at *B*. With hot riveting, the hole should be about $\frac{1}{16}$ inch larger than the rivet, but with cold rivets, the opening should be such that the rivets will slide in. Instead of backing up the head of the rivet, a dolly is applied to the small end, as indicated at *C*, and the driving is done on the head of the rivet by a set *D* and a hammer. The energy of the hammer is applied through the set to the rivet, which is upset or enlarged, as it is unable to move because of the mass of metal in the dolly. The metal of the rivets expands sidewise at *A* and *B*, completely filling the space. A feature of this method is that a part of the hammer blow is expended in forcing the plate *N* into contact with the plate *O*. The metal at *B* is prevented from moving sidewise

by a head formed at the dolly end of the rivet, and additional blows of the hammer tend to bring the plates closer and to hold them. The backing-in method is practical in making the various styles of rivet heads, particularly in making the thin, almost flush, head, and an advantage is that there are no reactionary stresses upon the thin head as would exist with the driven-in rivet.

As there is more demanded of the rivet replacing the old member, it is important that the work be carefully performed. This applies to the holes in the plate. All sharp corners should be removed, as they afford an opportunity for the rivet to shear off by external stress or to fly off under internal strain. A reamer, drill, or countersink can be used in removing sharp corners. The face left need not be more than $\frac{1}{64}$ or $\frac{1}{32}$ inch wide, in order to greatly strengthen the rivet at its weakest point, or where the head joins the body. By slightly

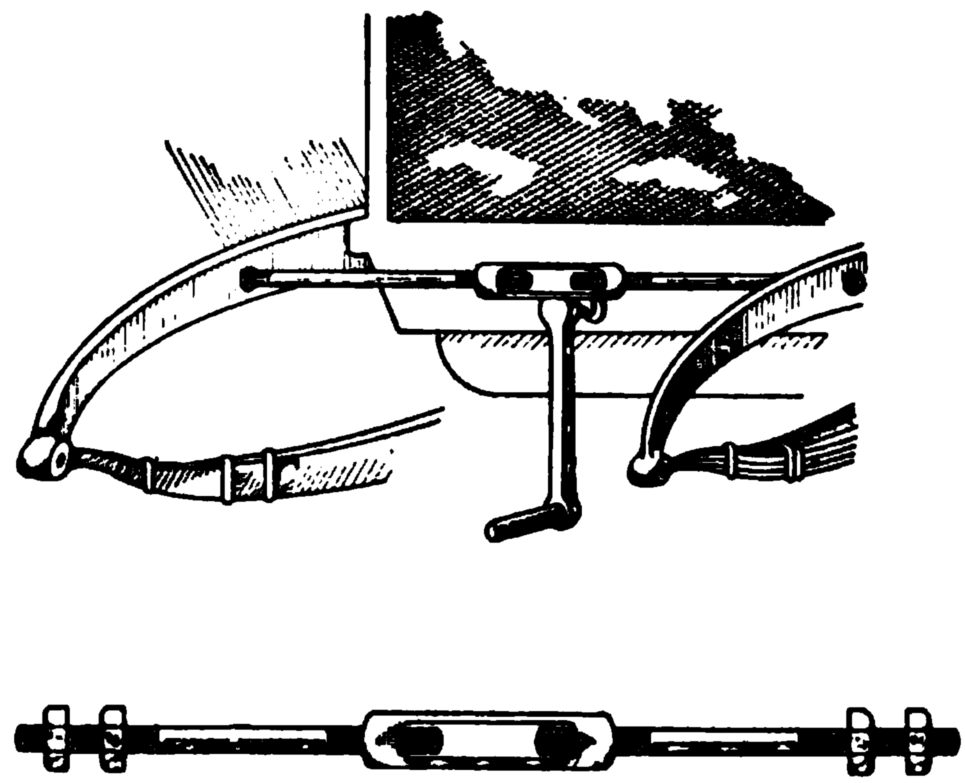


Fig. 392. Adding a Truss Rod to the Front of a Weak or Damaged Frame to Strengthen It and Preserve the Radiator

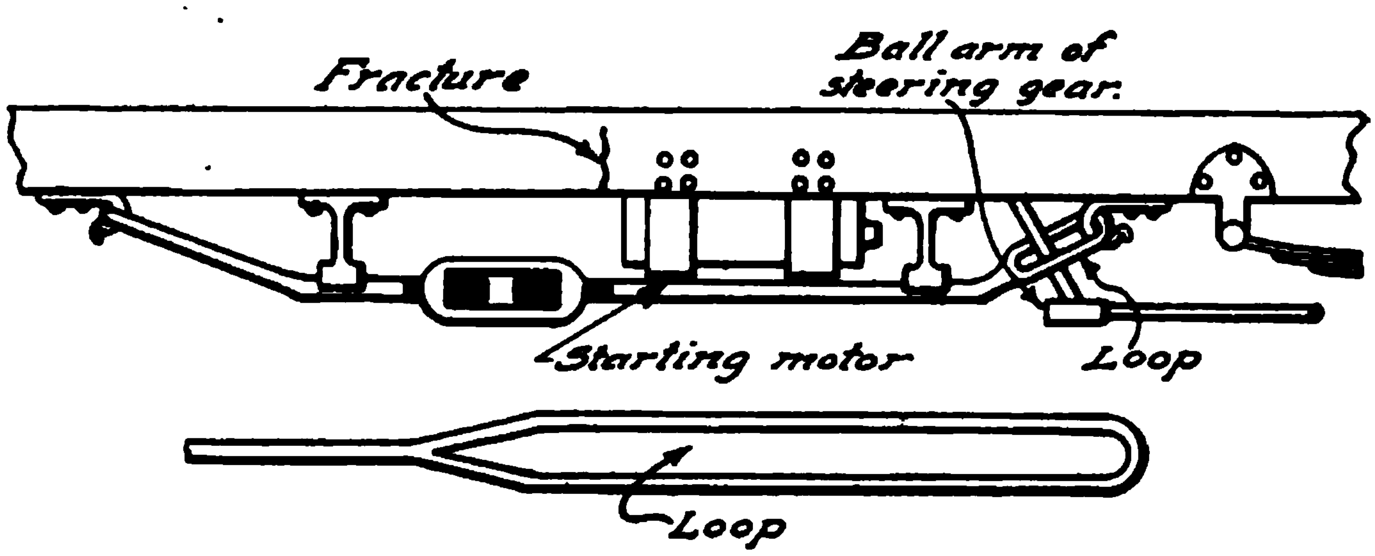



Fig. 393. Bracing Fractured Frame with Bar and Turnbuckle

chamfering the corner of the plate, the rivet is given a corresponding fillet, which not only increases its holding power but serves to draw the plates together.

**Frame Bracing Methods.** There are several methods whereby a frame that has been injured through collision or has sagged because

of too light construction can be repaired. The front of the frame is the chief offender in this respect, and many times a leaking radiator is the result. When repairs to the radiator fail to cure the trouble, it may be assumed that the frame is at fault. A simple remedy is shown in Fig. 392 and consists in bracing the frame by means of a rod and turnbuckle. The rod should be about 2 inches longer than the width of the frame and threaded for about 3 inches on each end. The turnbuckle is not essential, but it simplifies the work. In installing the brace, the inside nuts are screwed on first and far enough to allow putting the rod in place. These nuts are next screwed out until they bear against the frame, and the latter is forced out until any pressure that may have existed on the radiator is eliminated. The outside nuts are then screwed up snug. The advantage of the turnbuckle is that adjustments may be made as required.

Fig. 393 shows a method of trussing a frame that was fractured by the stresses of the motor starter. Even after the fracture had been repaired, the driving gear of the starter would not mesh properly with the ring gear on the flywheel of the engine. As the movement was up and down on the frame, a truss was found necessary; while it was a simple matter to attach one end of the truss on the left-hand side of the chassis, the right-hand side was more difficult because of the proximity of the ball arm of the steering-gear lever. The problem was solved by forming a loop at one end of the truss of sufficient width and length to permit travel of the ball arm. By utilizing a turnbuckle the desired tension was obtained.

## SPRINGS

**Basis of Classification.** The springs are important components of the chassis; for while the frame supports the power plant, clutch, and gearset, it is, in turn, supported upon the springs. The tendency at present is to design the frame and spring suspension so that the rear springs are placed very close to the rear wheels. In some cases, the frame is wide at the rear and is directly over the springs. Springs may be divided into seven general classes as follows: semi-elliptic, the full-elliptic, the three-quarter elliptic, the platform type, the cantilever, the quarter-elliptic, the coil, and combinations of these. The full-elliptic spring is made up of two sets of flat plates, slightly bowed away from each other at the center and attached together at

the ends. When these are used, the centers of the springs are attached top and bottom, respectively, to the frame and axle. With half of the top of the spring cut away, and the cut, or thick, end attached to the frame, this spring becomes a three-quarter elliptic. When the whole top of the spring is cut away, so that the spring is but a series of flat plates, bowed to a long radius, this becomes a semi-elliptic spring. By turning the semi-elliptic spring over, it becomes a canti-

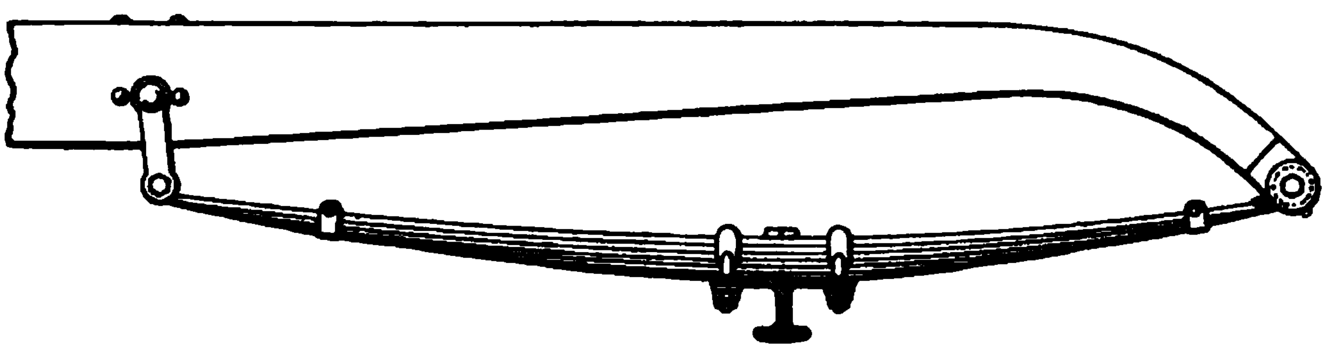


Fig. 394. Typical Semi-Elliptic Front Spring

lever when its center and one end are attached and the load applied to the other end. The quarter-elliptic is but a quarter of a spring, while the platform consists of three semi-elliptics—two as side members in the regular position, while the third is used as a cross-spring, being inverted and attached at the center to the rear end of the frame and at its ends to the side members. The coil form requires no explanation and is not now used on cars. In addition, these forms are modified by scroll ends and various attachments.

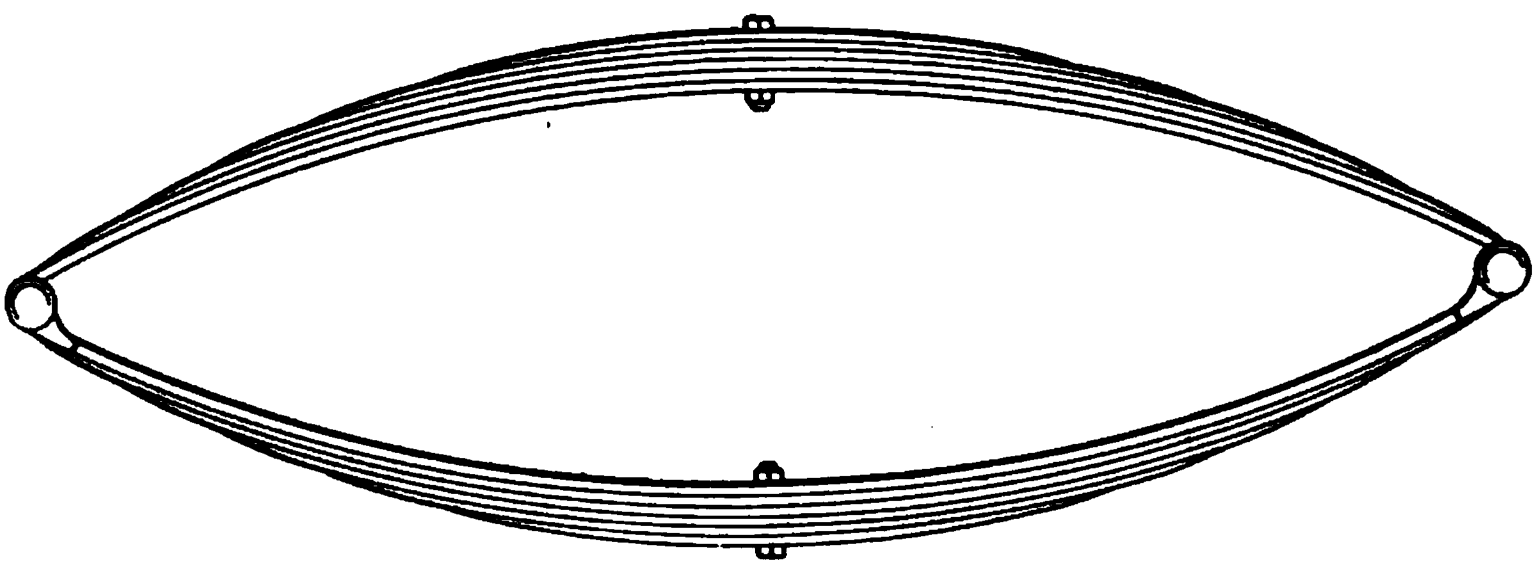


Fig. 395. Typical Full-Elliptic Front or Rear Spring

**Semi-Elliptic.** Fig. 394 shows a front spring of the semi-elliptic type, the form which is used now for almost every front spring. This is a working spring of the usual type, fixed at the front end, shackled at the rear end, attached to the axle in two places, and with two rebound clips in addition. The latter are put on the springs to prevent them from rebounding too far, in the case of a very deep drop. In some cases, as high as four, six, or eight of these clips may

be used. Many other springs are made with ears, these being clipped over the next lower spring plate, the final result being the same as the use of many clips, but with improved appearance.

**Full-Elliptic.** Full-elliptic springs are the oldest form known. Fig. 395 shows the construction of this type, the upper and lower parts being pivotally connected at the ends. A slight modification of this form, known as the scroll-end full-elliptic type, is in more extensive

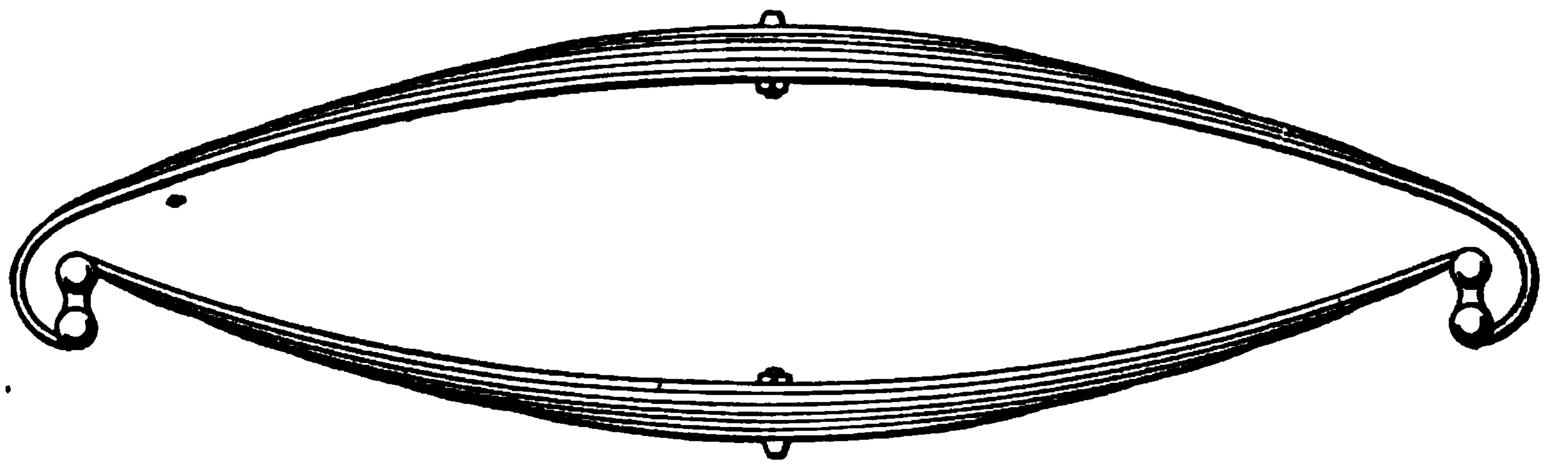


Fig. 396. Full-Elliptic Spring with Scroll Ends

use than the full-elliptic plain type. As Fig. 396 shows, the ends of the upper leaves are bent over. Each carries an eye, which is connected to the eye in the end of the upper leaves of the lower half of the spring by means of a shackle. This construction makes a very soft-riding spring.

**Three-Quarter Elliptic.** Very much like Fig. 396 is the form known as the three-quarter elliptic spring, the one having scroll ends being shown in Fig. 397. This form of spring is fastened at three

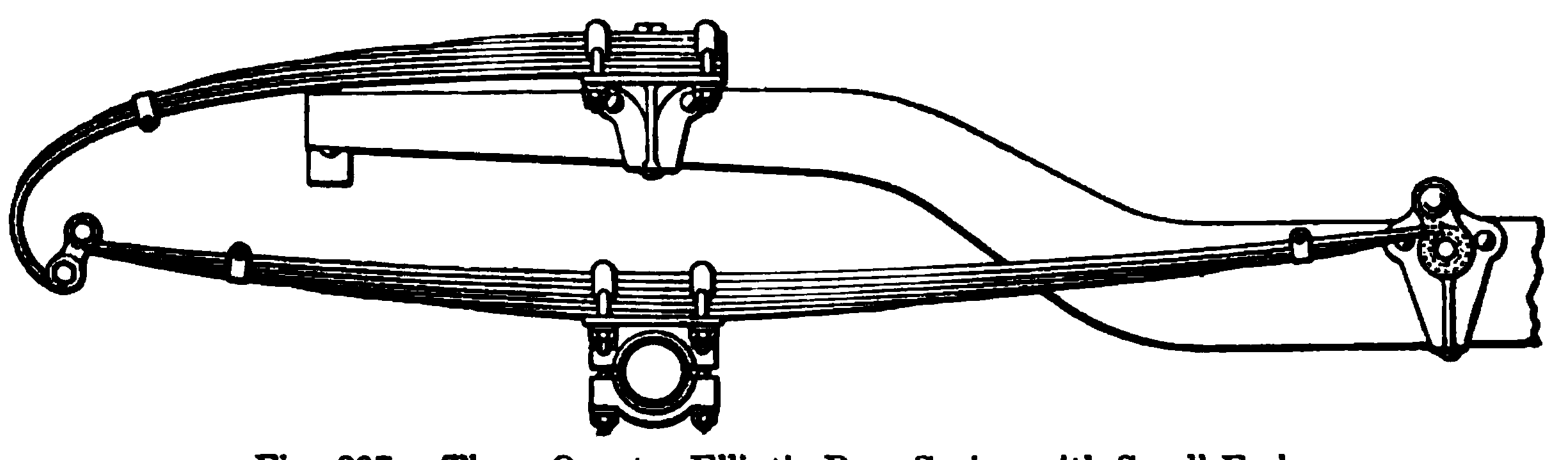


Fig. 397. Three-Quarter Elliptic Rear Spring with Scroll Ends

points. The lower part of the spring is shackled at the front end, fixed to the axle at the center, and shackled to the upper part of the spring at the rear. The upper part of the spring is fixed to the frame at the upper front end and shackled to the lower part at the rear. Fig. 407 shows another example of the three-quarter elliptic spring, which may differ in practice, as some three-quarter springs are not scroll ended.

This form of spring is growing in favor daily, a greater number being used this year than last, while designs for next year show a still

greater increase. One reason for this increase is the great increase in the number of dropped frames, that is, frames unswept at the rear. To this form of frame, the three-quarter elliptic spring is very well adapted and makes a very natural, very good, and very easy-riding combination.

**Platform.** The platform type of spring is used a great deal on large cars, as well as on very heavy trucks, on account of its ability to carry heavy loads well, and also on account of its flexibility. As may be seen in Fig. 398, it consists of three semi-elliptic springs shackled together at the corners. The rear cross-spring is usually made shorter than the two side springs, while the latter are set off center, making the front of the spring, that is, the part forward of the point of attachment to the axle longer than the part to the rear. There are two reasons for this: First, the front end acts somewhat as a radius rod, the rear end of the frame rising in an arc of a circle whose radius is the front half of the spring; second, this plan dis-

Fig. 398. Platform Springs, Showing How Side- and Cross-Springs Are Shackled Together

tributes the spring action equally in front of and back of the axle. Since the rear cross-spring is fastened to the frame in the center, each half of it is considered as a part of the side spring to which it is shackled. Thus, the total length of the side spring in front of the axle is the measured length of the side spring, while the total length of the side spring back of the axle is considered as the side length plus half of the cross-spring length. The center point, or point of axle attachment, is not moved so far forward as to make these two lengths equal, but in a proportion which may be derived thus: Assume a side spring 42 inches long and a cross-spring 35 inches long; then the spring would be set out of center some 4½ inches, making the front length about 25½ inches, while the rear length would be 16½ inches plus half of the rear spring, or 17½ inches, making a total of 34 inches. This would give a ratio of 25½ to 34, or 1 to 1.333. If the side members were 50 inches, the ratio would be about 1 to 1.25, and for side members shorter than 42, the ratio would be about 1 to 1.5.

**Cantilever.** The cantilever is, in appearance, a semi-elliptic spring turned over. It gets its name, however, from the method of suspension, which is quite different from that of any form of semi-elliptic spring. Moreover, as a part of this suspension, at least one

*Courtesy of King Motor Car Company, Detroit, Michigan*

end of the cantilever and sometimes two are finished up flat and square to slide back and forth in a groove provided for that purpose, a bolt through a central hole preventing the spring from coming out of its guide. One form, shown in Fig. 399, has a fixed attachment to the rear axle, a pivoted attachment to the frame at its center

Fig. 400. Front End of Cantilever Spring on Siddeley-Deasy (English) Car

(or slightly beyond the center), and a sliding attachment to the frame at its forward end to take care of the increase in length and of the forward movement necessary when the rear wheels rise.

Another form of cantilever is that shown in Fig. 400. This is the rear spring on the Siddeley-Deasy (English) car and, like that of

the King, is pivotally mounted on the frame just forward of its center. Unlike the King, however, the forward end of the spring has a shackle which permits it to swing when the rear axle rises or falls. This shackle is a very interesting feature of this installation, having an adjustment which is most unusual for a shackle, Fig. 401. Note how the outsides of the shackle have a series of grooves, into which the head of the shackle bolt on one side and the washer on the other, fit. By setting these in the desired grooves and tightening the nut, the position is fixed. If this does not give the proper throw, it is a simple matter to remove the nut and make a new adjustment.

Fig. 401. Detail of the Adjustable Shackle on Siddeley Cantilever Spring

In France, a form of double cantilever has been tried out with success; this form consists of a pair of cantilevers, one above the other, separated at the center by a carefully sized spacing block, which is pivotally attached to the frame. The rear ends are attached above and below the axle, while the front ends are attached to two fixed points. Although the ends are made much thinner and more flexible than those just shown, it should be noted that both of them are fixed. The rise and fall of the wheels must be taken up by the springs themselves, the pivot in the center simply distributing the distortion over both the front and rear halves.

*Advantages of Cantilever.* The advantages of the cantilever spring are the smaller unsprung weight and the reduced manufacturing cost for a given amount of flexibility. Another advantage is the absence of sharp rebounds and a greater deflection for a given load and length of spring; it also obviates the cut in the body required with the three-quarter elliptic spring. When the cantilever takes the driving strain, the main leaf is usually stiffened and, being stronger sidewise, it eliminates a good deal of the side sway. With torque rods, the main lead may be made lighter, as the starting, the braking,

Fig. 403. Unique Rear Spring of Marmon Cars

and the torque act through the torque rods. Since there is more metal in the line to the thrust, they are especially suitable for taking the thrust, and not quite as efficient in taking the torque.

**Hotchkiss Drive.** The adoption in 1915 of the Hotchkiss drive, Fig. 402, in which the rear axle is connected with the frame through the chassis springs only, making the springs perform the functions of torque and thrust, is a radical departure from previous forms. The objection that it subjected the springs to unnecessary strains has not been sustained in practice, which has shown that a slight yielding of the rear axle when starting and braking, by a certain flexure in the springs, has reduced the stresses upon the transmission members.

In the Hotchkiss drive, the springs are rigidly attached to the rear axle, while the front end of the spring is secured to the frame with a proportionately large bolt through which the drive is transmitted. Users of the drive claim that it is quieter, that the car holds the road better, that it is more flexible, and that it avoids the road shocks which are transmitted through stiff torque members from the axle to the frame. Makers who drive through the springs and employ other torque members claim that they are not sacrificing flexibility in driving while eliminating a certain side sway and other strains preva-

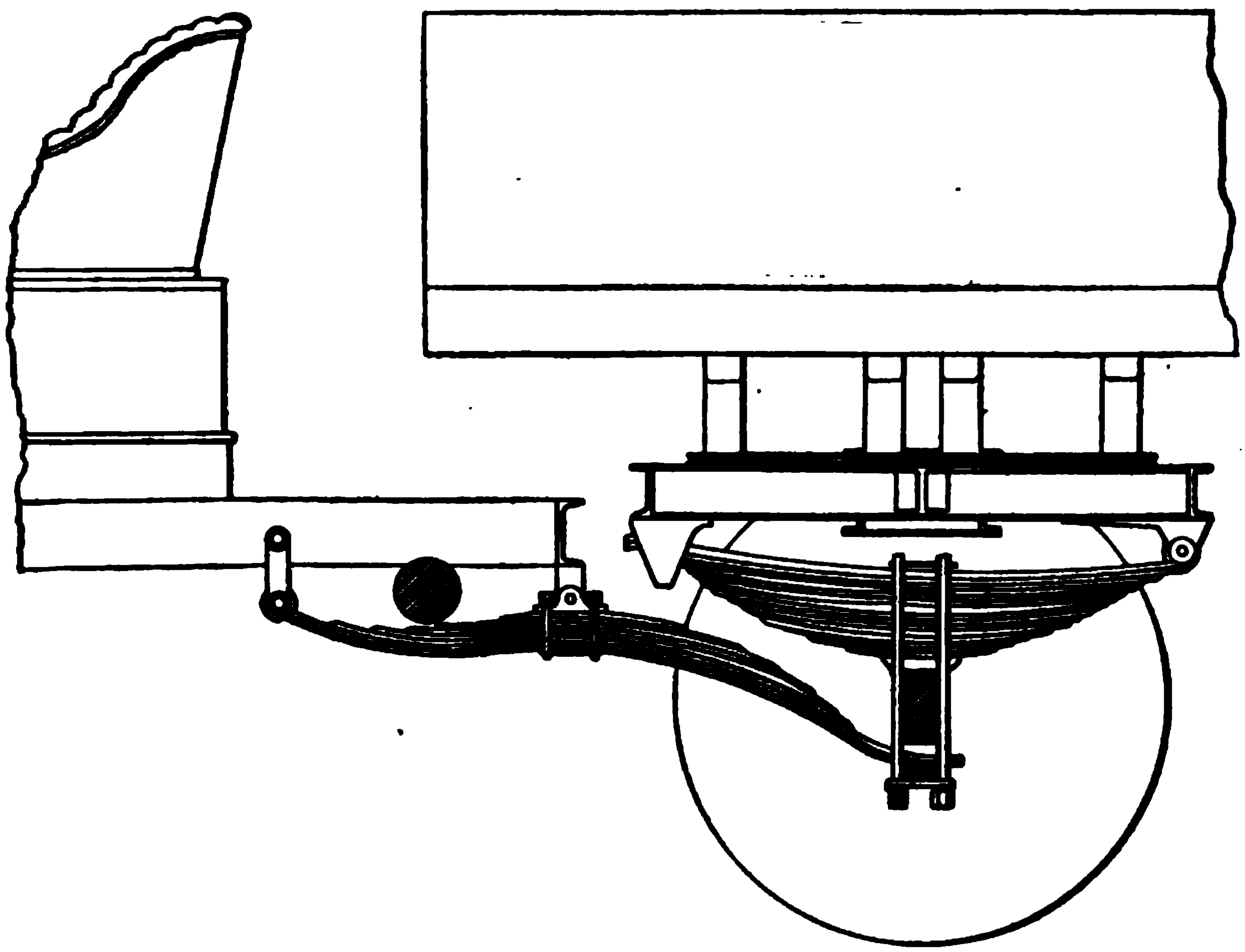


Fig. 404. Combination Cantilever and Semi-Elliptic Spring on Tractor

lent when the springs perform the functions of the torque. In the Hotchkiss drive, two universal joints in the drive shaft are used.

**Unconventional Types.** *Marmon.* A departure from conventional practice is the spring used on the Marmon car and shown in Fig. 403. It is a double-transverse construction, consisting of semi-elliptic springs bolted together at the center, with a curved block, or hard-maple cam, between them. This cam varies their stiffness, the spring automatically becoming stiffer as the load increases. Under normal load, the stiffness is about 170 pounds per inch, but as the springs are compressed the stiffness will reach 400 pounds. They

are shackled at one side and fixed at the other, obtaining a perfectly parallel motion to the frame. There is said to be no roll as is sometimes found with transverse springs.

*Knox Tractor.* An unusual method of suspension is that employed on the Knox tractor, a combination of a cantilever and semi-elliptic spring at the rear end of the frame. The design shown in

Fig. 405. Rear Spring of Six-Ton Truck

Fig. 404 includes heavy semi-elliptic springs, which are attached to the rear axle by long clips and carry the fifth wheel of the trailer. There is no connection between the springs and the tractor frame, so they carry the weight of the trailer and load only. The tractor frame is mounted on a cantilever spring having a pivot near its center and a shackle at the front end. The rear end bears on a seat clipped to the rear axle. This obtains a flexible mounting for the tractor and also permits the carrying of very heavy loads on the trailer.

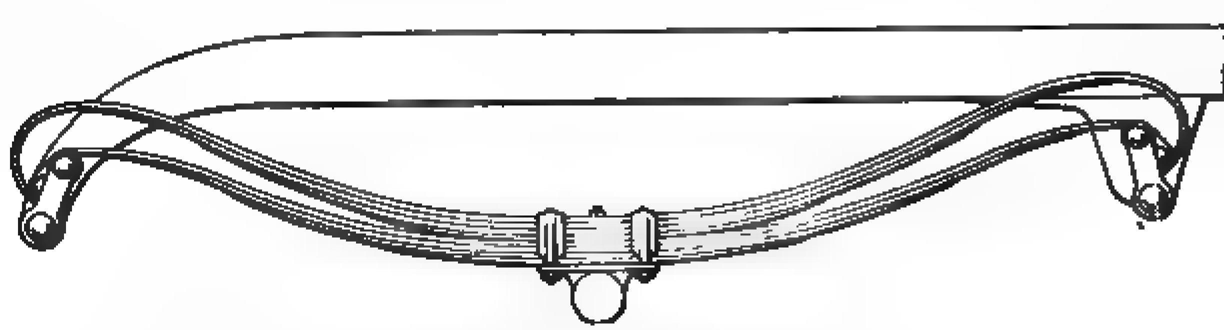


Fig. 406. Special Semi-Elliptic Rear Springs Formerly Made for Winton Cars
*Courtesy of Perfection Spring Company, Cleveland, Ohio*

*Semi-Elliptic Truck Spring.* The semi-elliptic spring is a favorite with makers of commercial vehicles. It is simple, and if the length, width, and other dimensions are proportioned correctly, it is a most satisfactory method for both front and rear suspension. Fig. 405 shows a rear spring for a 6-ton truck, the method of shackling, and how it is mounted on the axle by means of a spring seat.

***Winton.*** Many makers use their own special form of springs. **Fig. 406** shows the spring formerly used on the Winton cars, a type which might be described as a double-purpose spring. It was made in two parts, the lower part consisting of a regular semi-elliptic flat spring, while the upper part was a semi-elliptic flat spring with scroll ends. The central part of the spring was treated as one, being attached to the axle in the usual manner; the ends, however, had a peculiar appearance, because the upper and lower halves of the spring were of different shape. The scroll end of the upper part was supposed in itself to absorb many of the small road shocks. The spring was loosely attached to the frame at each end by means of a double

Fig. 407. Three-Quarter Scroll Elliptic Springs on Winton Car

shackle, made necessary by the double action of the spring; the tendency to flatten out increased its length, thus calling for a forward motion of the front and a backward motion of the rear ends, while the different lengthening action, owing to the difference in the lengths of the two parts of the spring itself, resulted in a turning about a different point.

For comparison with this earlier Winton spring, the latest form is shown in Fig. 407. It will be seen that the three-quarter elliptic form has been adopted, with a kick-up at the rear end of the frame. If the two types are compared somewhat closely, it will be seen that the only change in the frame part is the kick-up. The new springs show the scroll ends to which Winton has always been partial.

*Ford.* The form of the Ford spring has always been distinctly different. Fig. 408 shows the front and Fig. 409 the rear spring used on Ford cars, the distinction in the front spring being principally in the use of a single ordinary inverted front spring set across the frame on top of the axle, where most makers use a pair of side springs set parallel to the frame. This form is simple and cheap to make and assemble, the cost of the spring itself, and the work of putting

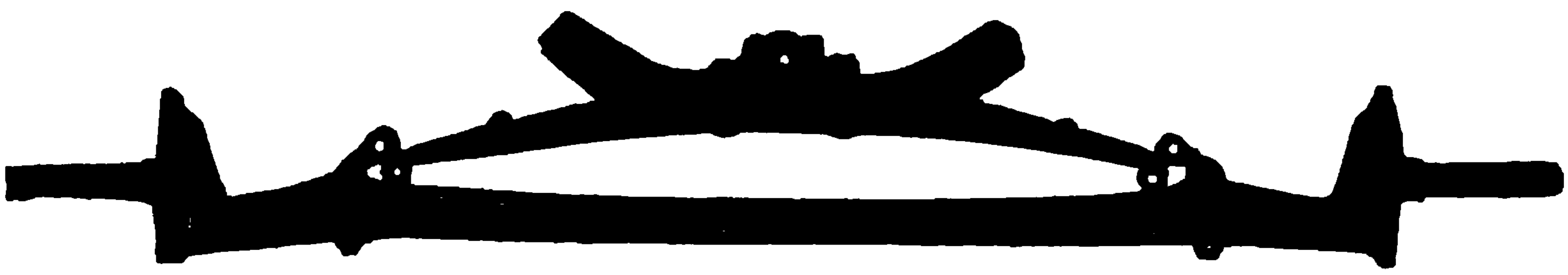


Fig. 408. Special Vanadium Front Springs for Ford Cars
*Courtesy of Ford Motor Company, Detroit, Michigan*

it on being just about half that of the spring attachment of the ordinary two-spring type. On the other hand, excellent riding qualities are claimed for it. A second distinction is that the spring is an inversion of the usual semi-elliptic type, the set of the spring being downward instead of upward. A third claim to distinction is in the use of vanadium steel, which, it is claimed, has a higher tensile and compressive strength than any other steel, and it is practically unbreakable in torsion. This steel is also being used in many other

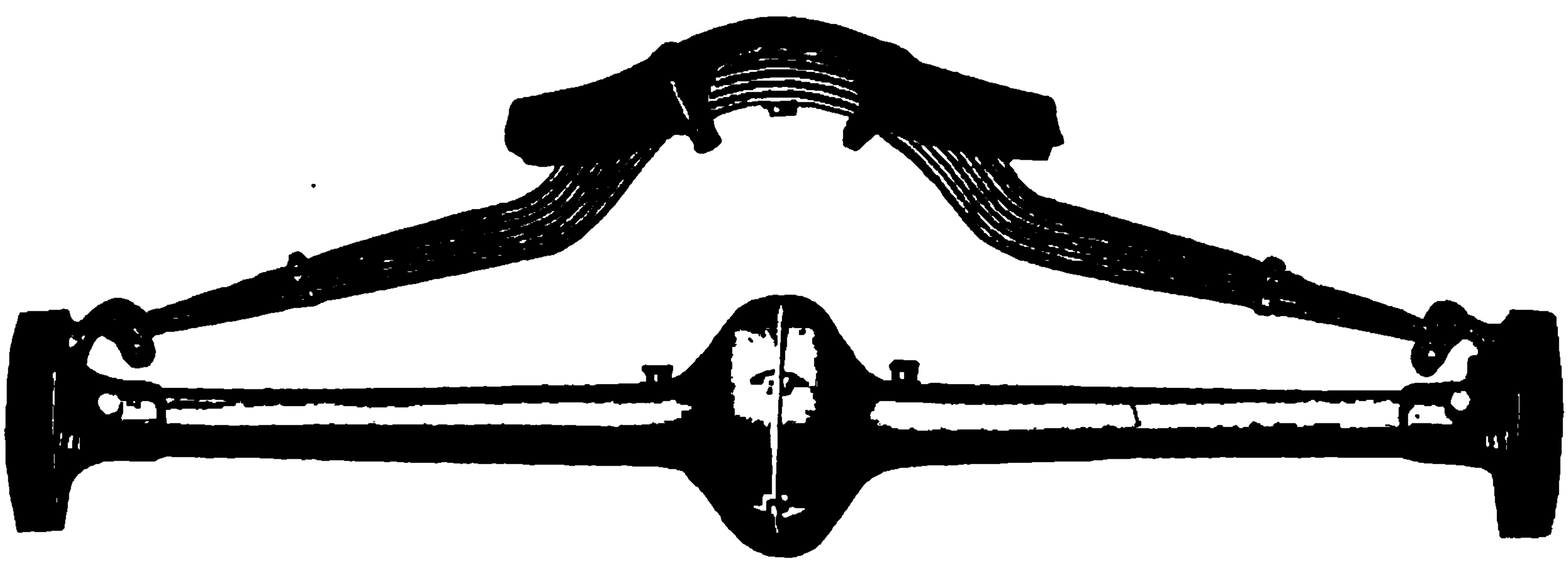


Fig. 409. Rear Springs of the Ford Car

parts, such as crankshafts, camshafts, fender irons, frames, drive-shafts, etc., resulting in a very light-weight car, since the greater strength of the material allows the use of smaller sections for equivalent strength.

The Ford rear spring has all the claims to distinction of the front spring, and, in addition, a hump at the center. Fig. 409 shows this hump clearly, the rear-frame cross-member being only partly shown. It will be noted that both ends of both springs are shackled,

in front, and full-elliptic scroll-end suspension at the rear. The method of shackling is similar.

**Varying Methods of Attaching Springs.** Springs are attached in many ways. For example, the one shown in Fig. 398 might be shackled at the front end, fixed to the axle, and fixed to the center of the frame at the rear, the side and cross-springs being shackled together. Again, the front end might be fixed to the frame, Fig. 412, all other connections being unchanged. Or, with either method of fixing the front end, the spring might be swiveled on the axle, so as to be free to give sidewise without changing the other properties of the spring. Or, with either method of fixing the front end of the spring, and with or without the axle swivel, the cross-spring might be pivoted at the central point so as to be free to turn in any direction

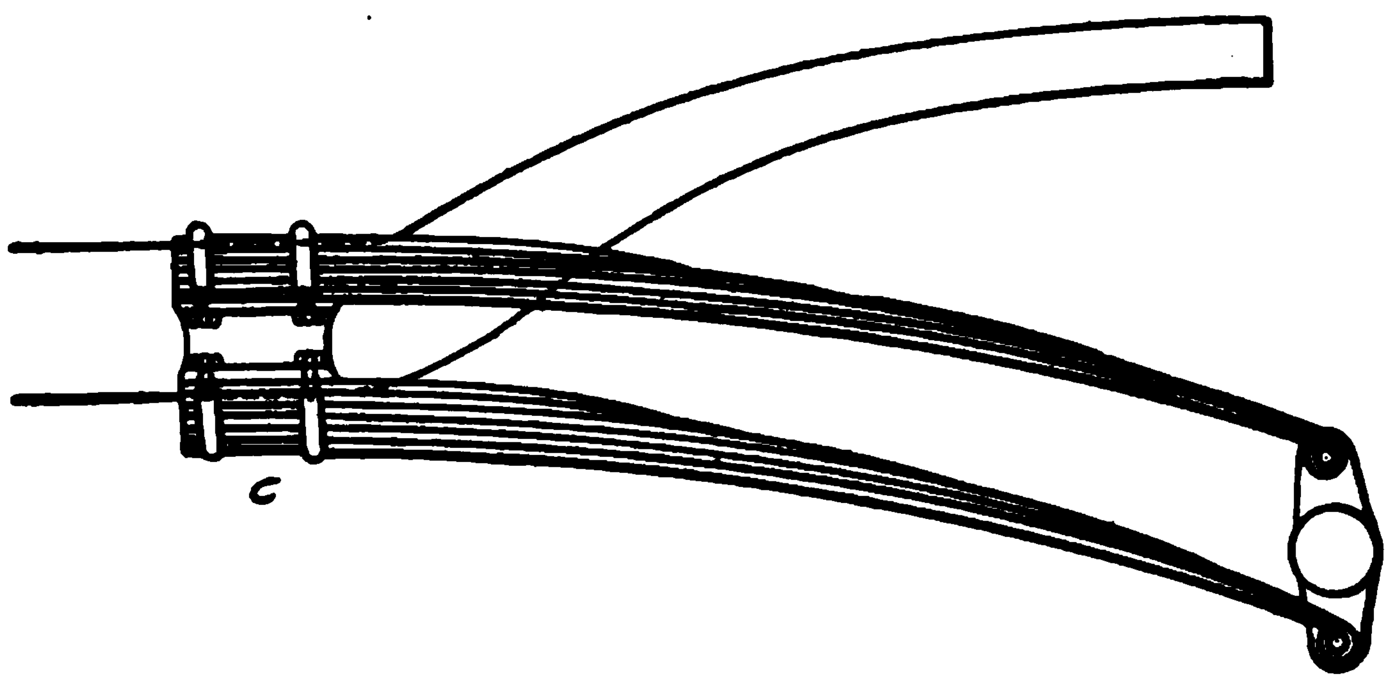



Fig. 412. Special Type of Double Quarter-Elliptic Rear Spring

about this central point. This latter method prevents binding and unequal spring action when one side of the frame is unduly raised or depressed, the solid method of fixing the rear end resulting in a double action on the part of one spring, owing partly to the tilting of the body and partly to spring action itself. With the pivot joint, the spring first swings about this point until a position of equilibrium is established, when the suppleness of the spring comes into action, the result being a deflection of half what it would be in the other case.

This form of spring also is used with the spiral spring, the latter taking the place of the shackle between the side and rear members. In this position it serves two purposes: (1) as a connector, taking the place of and doing the work of a shackle, thus acting as a universal and swinging joint between the two springs; (2) as a shock absorber, taking up road shocks within

its length, that is, in the coils, without transferring any of them to the body proper or, in case of heavier shocks, sharing with the side and rear springs. This, of course, is the true function of the springs—to allow the road wheels to pass over the inequalities, rising and falling as may be necessary, while the body travels along in a straight line, level and parallel with the general course of the road.

*Underslinging.* Almost any of the spring forms shown and described may be underslung, that is, attached to the axle from below. This is a quite common practice for semi-elliptic springs when used in the rear, but it is very uncommon for front springs. Similarly, full elliptics, whether having scroll ends or not, are frequently under-

Fig. 413. Rear-Spring Arrangement on 1917 Premier

slung. The three-quarter elliptic form when used in the rear is usually underslung; the platform spring is not underslung so often. The cantilever and quarter-elliptic springs have been mentioned in connection with the underneath attachment. It should be pointed out that the position beneath the axle lowers the center of gravity by an amount equal to the thickness of the spring plus the diameter of the axle plus twice the thickness of the attaching means, and this, too, without interfering with the quality or quantity of the spring action. In the case of the cantilever, the effect of underslinging is to reduce the straightness of the spring, that is, the form when attached above the axle is almost straight, while the form when fastened below the axle is very much curved—has considerable "opening".

**Shackles and Spring Horns.** Considerable improvement has taken place in the method of shackling springs, and provision is now made with some types of springs for the adjustment of the shackles and hangers as well as for renewing bushings. Reference has been made to the tendency of design in rear-spring suspension and to the underslung types. Fig. 413 shows the design employed with the 1917 Premier, and, as may be noted, the springs are slightly diagonal, the front ends coming inside the frame line, while the rear ends are attached to goose necks of a rear extension of the frame pieces. Shackles are used for connecting the ends of the springs to the extensions.

A departure from the conventional shackle is the safety double shackle used on the Rainer 1000-pound capacity delivery car, shown in Fig. 414. In addition to the main eye on the main leaf of the rear spring, the second leaf is extended and formed into an elongated eye, allowance being made for deflection under load. The eye of the leaf is attached to the frame by the usual rigid spring bolt. Additional means of support are furnished by clamps on either side of the spring, one by a pin through the elongated eye, and the other by a pin through the lower end of the clamp which takes in the third and fourth leaves. It is pointed out that in case the main leaf breaks the eye of the second becomes the driving eye, and should this break, the spring will wedge between the under pin and the upper part of the clamp, thus obtaining rigidity which is essential with the Hotchkiss method of drive.

Fig. 414. Double Shackle Used on Rainer Delivery Car

Although the general practice is to shackle the semi-elliptic front spring at its rear, a departure which places the shackle at the spring horn or in front is noted in the Manly truck.

**Adjusting Spring Hangers.** The type of front-spring hanger, shown in Fig. 415, is adjustable. This adjustability is accomplished by relieving the body of the grease cup and screwing in the slotted bolt which eliminates side play. The grease cup body acts as a lock nut. The rear hanger of the front spring, Fig. 416, is adjusted by loosening the inside lock nut and the body of the grease cup. After

removing the cap of the grease cup, the hanger bolt is turned out, or to the left, with a screwdriver, decreasing the distance between the links. The grease-cup body and lock nut are then set up tight.

Fig. 415. Section of Adjustable Front-Spring Hanger

Provision is made with some types of rear springs for eliminating play when the rear ends are mounted on seats.

**Spring Lubrication.** All springs now are fairly well lubricated. All shackles are provided with grease cups, and other points of attachment to the frame are provided with oil holes. Where the springs are pivoted either on frame or axle, a big grease cup is usually furnished. In addition, it is now realized that the maker can prevent much of the noise formerly coming from dry and perhaps rusted steel spring plates working over each other. There are several ways in which oiling is accomplished. The springs are made with an internal lip, or groove, which is filled with lubricant when they are assembled; or between each pair of spring leaves is placed

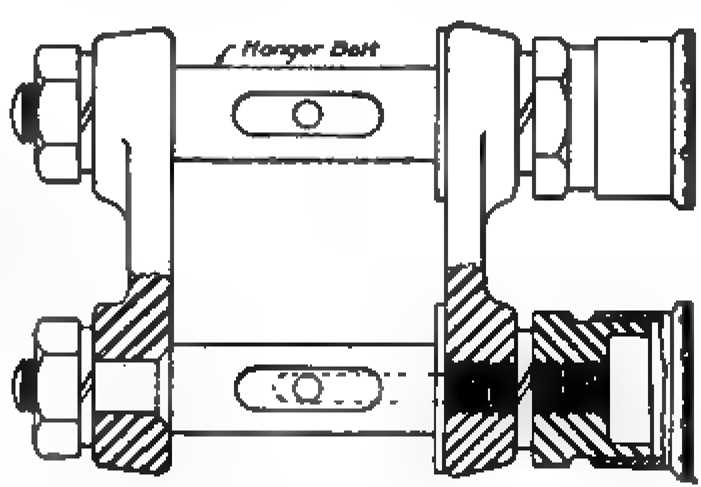



Fig. 416. Section of Rear-Spring Hanger

an insert having a series of oil pockets throughout its length, each filled with lubricant normally held in by means of a membrane cover; the movement of the spring plates and the heat generated thereby

starts the lubricant flowing to all parts. An even later method is the attachment of external cups, provided with a wick which goes around the spring leaves and is pressed against their sides. The wick is kept wet with lubricant from the cups, and the motion of the spring leaves, together with the capillary action in the wick, draws the oil in between the leaves.

**Spring Construction and Materials.** A study of the illustrations used will show that practically all modern springs are clipped together, the number of these clips varying with the length of the spring and the use to which it will be subjected. Thus, Winton, Fig. 407, shows three clips and a band. Some springs show as many as five clips and two bands. But none indicate the use of spring ears—very small projections on the ends of the leaves—which are bent over the edge of the leaf next below it to assist in holding the spring together, but they are in quite general use. Altogether, there are about 14 or 15 forms of spring-leaf ends, but those in general use may be reduced to seven. These are: the oval; the round point; the short French point, a modification of the oval; the round end with slot and bead; the ribbed form, widely used on motor trucks; the square point tapered; and the diamond point.

In addition, sizes have been standardized in America to the extent that only five widths are used for pleasure cars and seven for motor trucks. Those for the former are: 1½, 1¾, 2, 2¼, and 2½ inches; for the latter: 2, 2¼, 2½, 3, 3½, 4, and 4½ inches.

As the automobile business has called for better stand-up qualities under more severe conditions of use, the quality of steel used has been greatly improved, and other materials are better. The French make excellent springs, many of our best automobile manufacturers going abroad for their springs for this reason, but American springs are improving in quality so rapidly that this is becoming unnecessary. Formerly, all springs were of a plain carbon stock, but now a great deal of silicon, manganese, and vanadium steel are being used. Somè chrome and chrome-nickel steel have also been tried.

## SPRING TROUBLES AND REMEDIES

**Usual Spring Troubles.** *Lubrication.* The average repair man is likely to have more call to lubricate the leaves of a spring than any other one thing in connection with springs. True, they lose their

temper; they sag and show signs of losing their set; plates break in the middle, at the bolt hole, and near the ends of the top plate; and inside plates break in odd places. But more frequently the springs make an annoying noise, a perceptible squeak, because the plates have become dry and need lubricating. When this happens, and the up or down movement of the car rubs the plates over each other, dry metal is forcibly drawn over other dry metal with which it is held in close contact; naturally, a noise occurs.

To lubricate the spring, it is well to construct a spring-leaf spreader. Of course, the job is best done by jacking up the frame, dismounting the spring entirely, taking it apart and greasing each side of each plate thoroughly with a good graphite grease, then

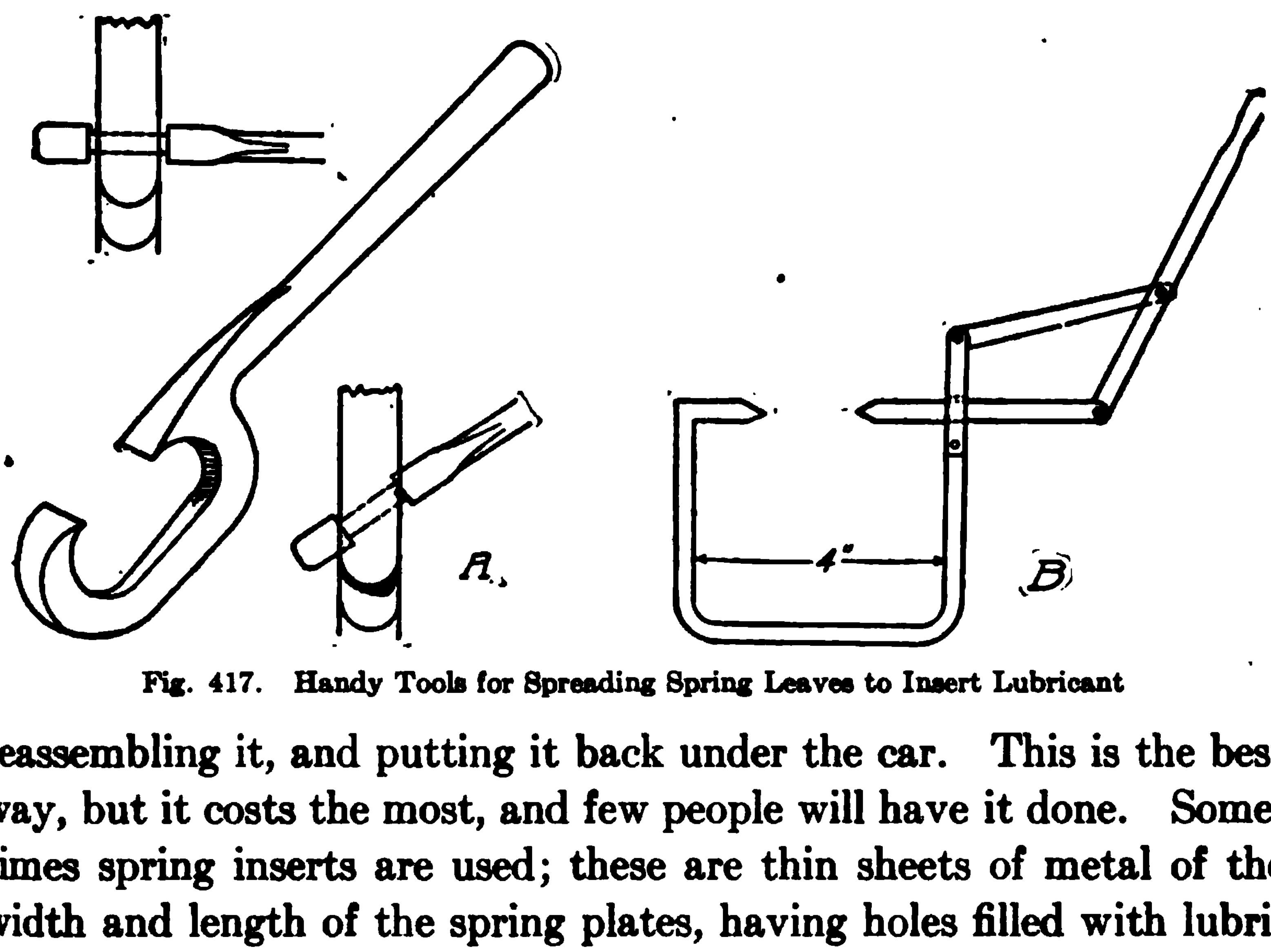



Fig. 417. Handy Tools for Spreading Spring Leaves to Insert Lubricant

reassembling it, and putting it back under the car. This is the best way, but it costs the most, and few people will have it done. Sometimes spring inserts are used; these are thin sheets of metal of the width and length of the spring plates, having holes filled with lubricant over which is a porous membrane.

For the ordinary spreading job, the plates must be pried apart and the grease inserted with a thin blade of steel, for instance, a long-bladed knife. To spread the leaves, jack up the frame so as to take off the load, then insert a thin point and force it between a pair of leaves. In Fig. 417, two forms of tools for making this forcible separation are shown. The first is a solid one-piece forging with the edges hardened. It is used by sliding the edges over the ends of the spring leaf, then giving it a twist to force it in between them,

as shown in the figures. The second tool is intended to be forced between two plates by drawing back on the handle.

*Tempering or Resetting Springs.* When springs lose their temper or require resetting, it is better for the average repair man to take them to a spring maker. Tempering springs is a difficult job, as it requires more than ordinary knowledge of springs, their manufacture, hardening, annealing, etc. When springs are in this condition, they sag down under load and have no resiliency. If a great many springs are handled, a rack like that shown in Fig. 418 is well worth making.

*Broken Springs.* When springs break, there is but one shop remedy—a new plate or plates. But when they break on the road, it is necessary to get home. When the top plate breaks near the

Fig. 418. Simple and Well-Designed Spring Rack

shackled end, repair this sufficiently to get home by using a flat wide bar with a hole in one end big enough to take the shackle bolt; bolt this bar to the spring in place of the end of the leaf which is broken.

**General Hints on Spring Repairs.** As a rule, a break in a plate takes place where it does not prevent operating the vehicle, but it should be borne in mind that the damage to the plate subjects the other plates to extra work, and, unless the broken member be properly repaired or replaced, the others are likely to break. If one of the intermediate plates breaks in the center at the bolt, tighten the spring clips as much as possible. Very frequently the rebound clips will be found to be loose, and missing clips also contribute to spring breakage.

The removal of a plate from or addition to a set is very likely to upset the grading of the construction. It is not practical to replace a broken plate with a new one because it is of the same width and thick-

ness, but an expert spring maker should be called in to see that the set, or fit, is correct. The fitting of a leaf requires the services of an expert spring man; while it appears to be a simple matter, the lack of knowledge by some claiming to be spring experts is responsible for breakage after the spring has been repaired. The spring clips and the nut of the center bolt should be kept tight. The importance of preventing the accumulation of rust on the leaves and of lubrication has been commented upon.

## SHOCK ABSORBERS

**Function.** The ordinary flat-leaf springs of any of the types previously described are inadequate for automobile suspensions. When the springs are made sufficiently stiff to carry the load properly over the small inequalities of ordinary roads, they are too stiff to respond readily to the larger bumps. The result is a shock, or jounce, to the passengers. When the springs are made lighter and more flexible in order to minimize the larger shocks, the smaller ones have too large an influence, thus keeping the body and its passengers in motion all the time. These two contradictory conditions have created the field for the shock absorber.

The shock absorber is generally a form of auxiliary spring, the function of which is to absorb the larger shocks, leaving the main springs to carry the ordinary small recoils in the usual manner; in short, to lengthen the period of shock. This is done in a variety of ways, and, as might be expected, by a great variety of devices.

**General Classes of Absorbers.** The simplest forms of absorbers are the ordinary bumper, or buffer, of rubber and the simple endless belt, or strap, encircling the axle and some part of the frame and acting as the rubber pad does—simply as a buffer. There are the following classes of the more complicated shock-preventing and shock-absorbing devices: (1) frictional-plate or cam, in which the rotation of a pair of flat plates pressed together tightly—one attached to the frame, the other to the axle—opposes any quick movement of the two or of either one relative to the other; (2) a coil spring used alone and in combination—alone it is used in the plane of the coil, or at right angles to it, and parallel to the center line about which the coil is wound, while in combination it is found joined with the simple leather strap or with another coil spring of equal or sometimes of less

strength, in the latter case the weaker one acting with the main springs; (3) the flat-leaf spring, a more simple description of which would be a small duplicate of the main semi-elliptic spring set on it so as to oppose its action; (4) the air cushion; and (5) the liquid device, in simple form and in combination with some one or more of the coil-spring forms.

**Frictional-Plate Type.** A frictional-plate type of shock absorber is shown in Fig. 419. This absorber consists of an upper arm attached to the frame, having at its outer end a frictional plate in contact with a similar plate at the upper and outer end of the other arm pivoted to the axle. The two plates are pressed together by means of the nut shown in the center; this nut is resisted by the spring beneath it and the slightly arched surfaces of the plates. When a sudden bump raises the axle, it must turn the two faces of metal across each other to the limit before it can lift the body. As will be seen, this means a considerable distance, and it can be made relatively greater by clamping the nut up tighter, thus increasing the friction between the surfaces, and, therefore, requiring greater force to turn them. Because of this adjustable quantity of friction, this type is called the governed friction type.

Fig. 410. Hartford Governed Friction Type of Shock Absorber
*Courtesy of Hartford Suspension Company, Jersey City, New Jersey*

When cams are used, practically the same result is obtained, except that the device is necessarily more complicated. The cam action usually generates some heat, and, for this reason, this form of shock absorber is most always enclosed, and the interior, where the cam works, is filled with grease or very heavy oil.

A modification of the plain frictional-plate form is seen in Fig. 420, which is called a passive range absorber, because, for ordinary movements of the springs to which it is attached, it does not come into action. When the usual spring action is exceeded, however, as in a

sharp jounce, the device becomes effective. It appears much like the Hartford just shown, but the construction is decidedly different. The upper, or frame, arm is threaded to receive an Acme-threaded screw, which is carried by the lower, or axle, arm. The action of screwing this out tends to force the plate on the lower arm, which must move outward with the screw against a rubber washer held firmly by the outside nut and cover plate. Thus, the scissors action of the two arms on a sudden movement is resisted by the compression of the rubber washer. This compression can be increased or decreased by tightening or loosening the slotted outside nut, so that the screw is given less or more movement. The rubber washer is made with a series of holes in it to allow of compression.

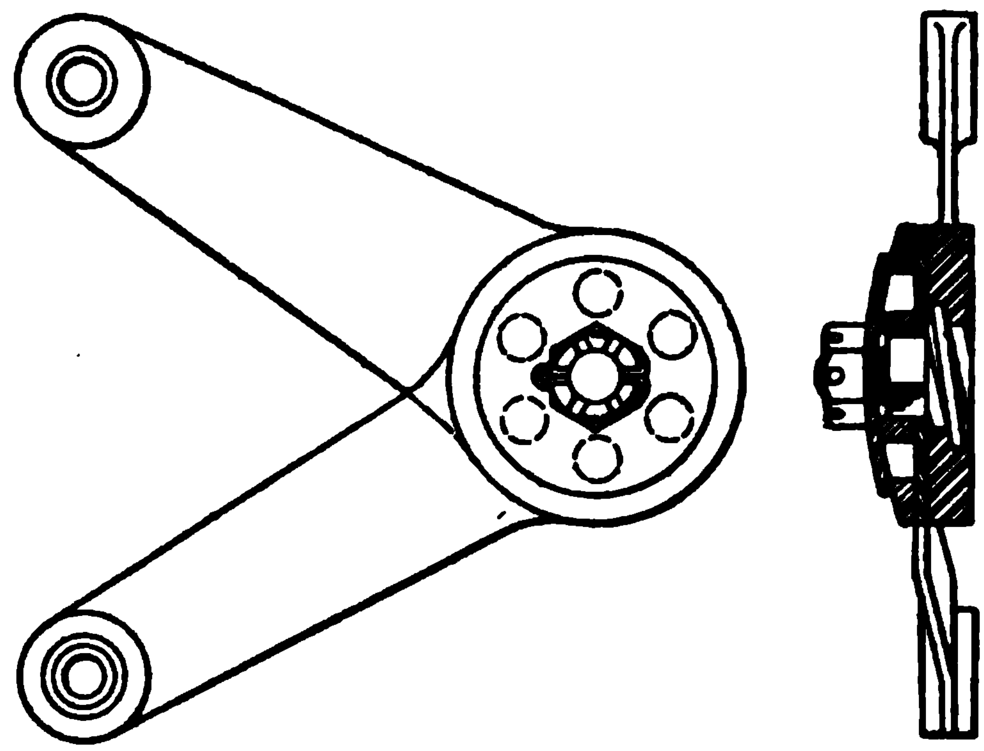


Fig. 420. Laporte Passive Range Friction Type of Shock Absorber
*Courtesy of Charles Laporte, Detroit, Michigan*

**Coil Springs, Alone and in Combinations.** *Springs Alone.* The coil-spring absorber is probably the most widely used form, primarily because it is both good and cheap; furthermore, it is simple and adds little weight. In most instances, the coil is so placed as to compress along the direction of its center line. One device, however, the Acme, shown in Fig. 421, works at right angles to this. It consists of a pair of coils, the two ends of each being so constructed as to go on the ends of the shackle bolts in place of the usual shackle. When the shackle is removed, one pair of ends is fastened to the spring in place of the shackle, while the other pair of ends is fixed to the frame

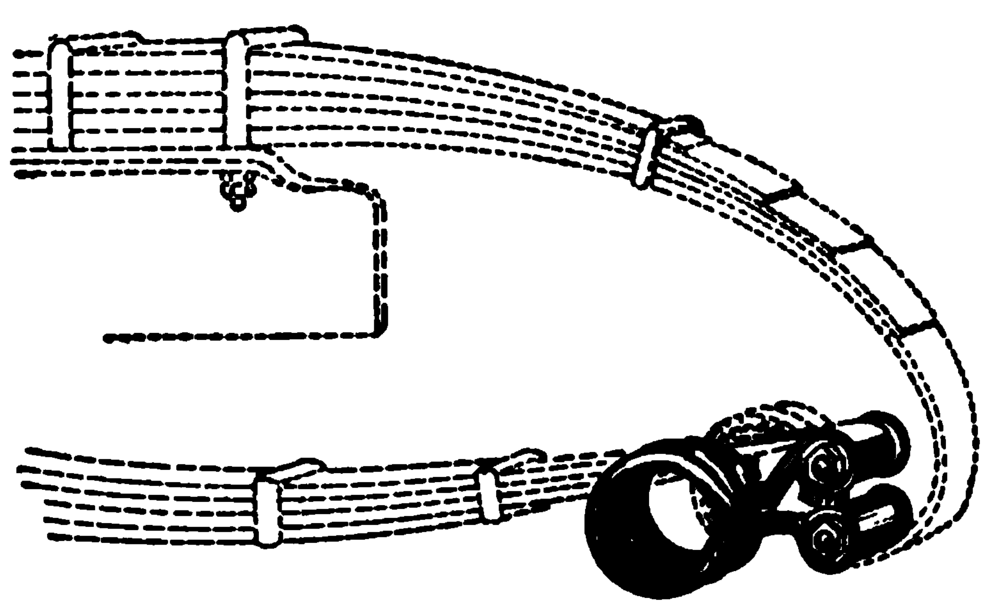


Fig. 421. Acme Torison Spring Fitted to Three-Quarter Elliptic Gears
*Courtesy of Acme Torsion Spring Company, Boston, Massachusetts*

or the other part of the spring, as the case may be. Note that this arrangement brings one of the coils on either side of the main spring end, extending away from it in a horizontal plane. In this position, the torsion spring acts as a spring shackle, absorbing the jounces and bounces so that they do not reach either the body, the attaching point, or the other half of the spring, as the case may be.

Fig. 422. Sager Equalizing Springs Are Very Simple in Construction
*Courtesy of J. H. Sager Company, Rochester, New York*

Fig. 422 is a simple coil spring of barrel shape, that is, the end coils are smaller than those in the center and are set between frame and axle in such a way that they absorb the jounces directly. This is probably the simplest possible shock-preventing device, consisting only of the spring and its top frame and bottom axle connections. These are made in four sizes of wire, varying from $\frac{5}{16}$ inch up to $\frac{13}{32}$ inch.

In the K-W road smoother, shown in Fig. 423, the action of the spring is opposed by an air chamber at the top, creating a balance. A shock which causes the spring to move is opposed by the spring itself, while the rebound, or reaction, is opposed by the air compressed in the air chamber.

Fig. 423. K-W Spring Type of Road Smoother

*Combinations.* Probably exceeded in simplicity only by the two forms just shown is the type in which a coil spring and leather band, or strap, are combined. One of these, the Hoover, is shown in Fig. 424. It will be seen that the spring end is fastened to the body, while the strap is

attached to the lower end of the spring and encircles the axle. Hence, this will not interfere with upward movements of the axle, but only with the downward ones, that is, the axle is free to rise, but as soon as the car body starts to rise, the strap-spring combination acts to prevent it. This is particularly true if the axle has reached the limit of its motion and has started downward before the body starts upward. In that case, the body can move upward only the amount of slack in the strap plus the give of the spring, but minus the amount the axle has already moved downward. This inexpensive arrangement has found great favor on small cars.

Fig. 424 Hoover Shock Absorber, a Spring and Strap Combination
*Courtesy of H. W. Hoover Company, New Berlin, Ohio*

*Double-Coil Spring Types.* In principle, the use of two springs is not different from the use of one. For structural reasons, however, it is easier to attach the two-spring form, while dividing the load up into two parts allows of the use of smaller diameters and smaller sizes of wire, thus making the device appear more compact. One of the two-spring forms, the J.H.S., is shown in Fig. 425. It consists of a pair of cylinders with coil springs within. The tops of the two cylinders are joined by a pin, and this joining pin is attached to the lower leaf of the spring. Inside the cylinders, pistons are set above each spring, and these are connected, this connection being used for the other half of the spring. At the bottom, the external bands on each of the two cylinders are connected, so as to keep them parallel at all times. Thus any movement upward of the lower part of the

Fig. 425. J.H.S. Shock Absorber Has Twin Springs Encased

main-leaf spring tends to draw the enclosure for both shock-absorbing springs upward. The springs themselves resist this and absorb a large part of the movement both in force and distance.

**Flat-Plate Recoil Springs.** The third class, or flat-leaf spring, is a semi-elliptic unit in miniature. It is placed upon the top of the ordinary semi-elliptic spring, but it is reversed and has a spacing plate between the two. The object of this plate is to prevent recoil and to eliminate the rebound of the car body without restricting the flexibility of the main springs. As shown in Fig. 426, the Ames equalizing spring is constructed along these lines. As will be noted, this allows all downward movement of the spring, having no influence thereupon; but when the recoil, the upward equal and opposite reaction, comes, the smaller upper spring opposes this reaction and

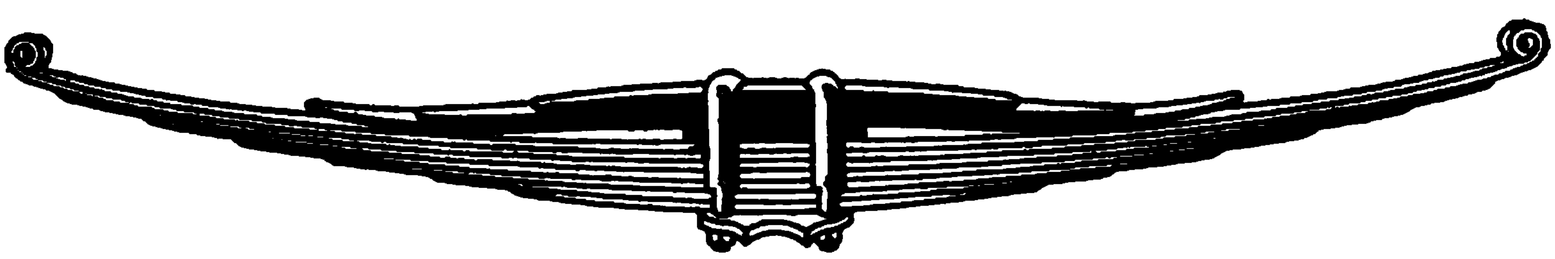


**Fig. 426. Ames Equalizing Spring Is a Simple Small Inverted Semi-Elliptic**
*Courtesy of Clarence N. Peacock and Company, New York City*

minimizes it, so that little or none of it reaches the body or the passengers.

**Air Cushion.** Perhaps the most complicated form of shock absorber—certainly the most expensive and at the same time the most efficient—is the air cushion. This form consists of a pair of telescoping cylinders one being attached to the frame and the other to the spring. When road obstructions cause the spring to rise, it pushes its cylinder upward, but this movement is resisted by the air inside of the cylinders. With the amount of air properly proportioned to the size and weight of the car and its load, all this upward movement will be absorbed and none will reach the body and its occupants.

This rough outline describes the Westinghouse air spring, shown in cross-section in Fig. 427. In order to handle the air pressure and keep the cylinders within the commercial limits, oil also is used in the cylinders. This reduces the volume of contained air; but, for each inch the device is compressed, the air is reduced by a greater percentage of its original volume, consequently the resistance to compression is greater than it would be without the oil.

In the drawing, *A* is the upper section of the cushion chamber, telescoping into the lower section made up of tube *B* and crosshead *E*. The outer tube *C* is simply a guard. A steel casting *D* is bored out to form a guide for the outer tube and crosshead, and has a rectangular pad *F* machined for bolting the whole device to the bracket attached to the frame of the car. A shackle *G* is fastened to the end of the car spring *I* and is pivoted to the crosshead *E*. Packing ring *H* is used to make the inner cylinder a tight fit in the outer casing. A breather *J* is placed on the side, through which air is drawn by the upward movement of tube *B* through the medium of the tightness of packing ring *H*, just mentioned, and this air, on the downward movement, is forced through the passage *K* to a port partly surrounding the tube *B*. There is no packing ring between this tube and its guide *D*, so the air blows out and keeps the contacting surfaces clean. A further protection is afforded by the felt-wiper ring *L*,

Fig. 427. Section through the Westinghouse Air Spring, Showing Construction and Operation
*Courtesy of Westinghouse Air Spring Company, Pittsburgh, Pennsylvania*

which retains the grease in the groove just above it. $O$ is a rod connecting the two front or rear springs. At the top is the screw cap $M$, covering the air valve $N$, which is designed to be used just as the air valve in a tire.

The lower part of the device is filled with oil up to a level which approximates the line $Z$, all above this level being air under pressure. Consequently, the device actually compresses the air through the medium of the oil, which is incompressible. This oil forms a seal for the air chamber and prevents its leakage, although the oil itself is allowed to leak through, this leakage being pumped back automatically by the action of the springs. This works out as follows:

Fig. 428. Westinghouse Air Springs Applied to the Rear of Pierce Limousine

In what might be called the piston, although it is not, because it does not move—the other parts moving relative to it—there is the plain leather packing ring $P$ and the cup leather $R$ held out against the sides of the cylinder by the conical ring and spring.

The small amount of oil which does leak past the packing rings $P$ and $R$ is caught in the annular chamber $S$, whence it flows down through the vertical (dotted) passage $Q$ into the chamber just below the ball valve $T$. In the center is a hollow plunger $U$ of a single-acting pump. This has two collars on its upper end $V$ and $W$ and between them a disc $X$. This almost fills the passage just above it. The plunger is held down by the light spiral spring shown pressing on the collar $V$.

When a road obstruction is met and the spring rises, crosshead $E$ rises and the upward movement of the oil takes the disc $X$ upward until it strikes and carries with it collar $V$, which lifts the plunger and draws in a charge of oil. When the air compressed in the upper chamber of the device expands, and the car spring $I$ and crosshead $E$ go down again, the oil flows in the opposite direction, carries disc $X$ down against collar $W$, and forces the plunger downward. Then the oil passes the ball check $Y$, goes through the hollow plunger, and is discharged back into the upper, or air, chamber. In the first place, the oil is put in by taking off cap $M$ and taking out the air valve $N$. Then a special single-acting oil gun is used to force it in, a long nozzle being necessary to reach down into the interior, with a stop to limit this downward distance. The maker recommends that an excess be put in and then slowly drawn off to the right level.

Fig. 429. Typical Semi-Elliptic Overload Spring

As will be seen from the foregoing, this device is essentially an air spring, and the air cushion does the work; but it is the oil below it, with its permissible leakage and with a pump to return this leaking oil, which makes this device practicable. To show the exterior, the part which most persons would see and remember, Fig. 428 is presented. This figure shows the rear end of a Pierce limousine equipped with a pair of the Westinghouse air springs. Note the breather, tie rod, cap at the top, cast guide at the bottom, and other parts previously shown and described.

**Hydraulic Suspensions.** The majority of the hydraulic devices developed as shock absorbers consist of turning vanes connected to the axle or spring, enclosed in a liquid-tight case filled with some heavy oil. There is a hole of small diameter in the case which connects the two sides of the vane, its motion forcing the fluid through this hole.

Thus the spring action simply pumps the oil from one side of the vane to the other and back again, the resistance to the flow of the liquid past the vanes and through the small hole absorbing all of the shocks.

**Overload Springs.** Overload springs are utilized with commercial vehicles and may be of either the leaf or coil type, and so arranged as to act only when the load on the main springs reaches a certain weight. The wear plate may be a separate platform, as shown in Fig. 429, or it may be formed integral with the pressure block. Where coil springs are used, they are made of square section, attached either to the frame cross-member or to the axle. Two such springs are used, one on each side. The design in Fig. 429 is a semi-elliptic. It is attached to a frame cross-member, and the ends are free so that they may make connection with a separate spring seat or a pad on the pressure block of the side spring when a predetermined load has been applied. With some trucks the front springs are mounted on a seat forged integral with the axle and are retained by box clips; a coil spring is attached to the pressure block, which acts as a bumper. Under excessive deflections these springs strike the bottom flange of the frame and arrest the rebound motion of the vehicle spring. The Jeffery Quad employs a spring bumper which is made of flat metal and is termed a volute spring. It is attached to a bracket fastened to the pressure block.

## SUMMARY OF INSTRUCTIONS

### STEERING

**Q. Which wheel travels farther on curves and why?**

A. The outer wheel must travel much farther on any curve, or turn, because it is turning through an equal angle on a curve of much longer radius. On very short turns, the distance the outer wheel must travel can be more than 50 per cent greater, or longer, than that of the inner.

**Q. What general condition exists which makes the problem of steering so complicated to lay out?**

A. The answer to the previous question gives an idea of the demands on the steering gear. The difference in the distances which the two wheels must travel on all curves—some differences being as high as 50 per cent, and with the difference shifting from one side to the other—is the general difficulty.

**Q. How does the usual steering arrangement care for this?**

A. By having the linkage which connects and steers the front wheels arranged so that a prolongation of the center lines of the two steering arms will pass through the center of the rear axle.

**Q. How does this solve the difficulty?**

A. When this arrangement is used, any swing or turn given to the steering system, say a turn to the right, will swing the left-hand knuckle through a larger angle than the right, although the two are connected together by linkage. This means that the inner, or left, wheel will swing about a shorter radius than the outer, or right, wheel, since if the two were turned through equal angles, the two radii would be equal.

**Q. What other items complicate this steering problem?**

A. The fact that the wheels themselves must toe in slightly at the front in order to steer easily and hold a straight line when set straight. Furthermore, the wheels must be set with their tops wider apart than their bottoms so that the line through the center of the plane of the wheel strikes the cambered, or raised, road surface at a right angle; this makes the whole situation even worse.

**Q. Is the ordinary front axle of such a design that it gives perfect steering?**

A. No. But it represents a working approximation which could not be improved upon without many needless complications. On a sharp turn, probably one wheel is dragged around the curve for a small portion of its length, but the distance is so small that it would never be noticed by the eye nor discovered in any difference of life in the tires.

**Q. How is the turning of the steering knuckles about their pivots obtained?**

A. The swinging movement of the steering knuckles is obtained through a fore-and-aft movement of the steering rod connected up to one of the steering-knuckle arms by a ball joint.

**Q. How is this longitudinal movement of the steering rod obtained?**

A. By a fore-and-aft swinging of the steering arm attached to the steering gear.

**Q. How is this fore-and-aft movement of the steering arm produced?**

A. By the partial rotation of the gear within the steering gear itself.

**Q. And how is this partial rotation of the gear developed?**

A. By the turning of the hand wheel, which turns the worm. The hand wheel is fastened to the upper end of the steering post proper (as distinguished by its stationary brass cover), while the worm is fixed to the lower end of it. Consequently, whenever the hand wheel is turned, the worm must turn also.

**Q. Why are the worm and the gear used for steering gears?**

A. The worm is used to secure irreversibility, as it is one of the few forms of mechanism which will not transmit power back through the entire group in the reverse direction, that is, it will not allow a movement of the wheels to be transmitted back to the steering wheel against the driver's wishes. In addition, it is compact, noiseless, easy to care for, wears little, and is highly efficient.

**Q. What other forms of mechanism are used for steering gears?**

A. Bevel gear, screw-and-nut, double screw, worm gear and full gear as distinguished from worm gear and partial gear, spur gear, simple bent lever, and other forms.

**Q. What are the disadvantages of these forms?**

A. With the exception of the worm and full gear, all are wholly or partially reversible, so if the front wheels strike an obstacle, the shock is transmitted back to the driver's hands.

**Q. How are steering wheels made?**

A. In various ways. Some are rings of glued-up wood, to the underside of which the arms of the steering-wheel spider are fastened. Others have the arms cast integral with the aluminum rim; still others are of bronze with a molded rubber surface applied to the bronze ring.

**Q. Is the wood form, with spider fastened to it, popular?**

A. It was, but it is rapidly going out in favor of something better. This construction is now used only on the cheapest cars and not on all of those.

**Q. What are the advantages of the hinged, or folding, steering wheel?**

A. Folding up the wheel out of the way allows the driver to get out on the lever side of the car, which might be practically impossible otherwise. It allows stout drivers more comfort in getting in and out. It is also an advantage when working in the front compartment of the car.

**Q. What is the importance of the cross-rod at the front axle?**

A. It is the only member tying the two steering knuckles together. If this rod is bent, the wheels cannot be steered accurately; if it is broken, they cannot be steered at all. In fact, the car cannot be moved forward when the rod is broken.

**Q. Why is the rod usually placed behind the front axle?**

A. As a protection against damage from high spots in the road. If it is back of the axle, it is well protected; but if the design places the rod in front of the axle, it has no protection, and trouble is likely to ensue on rough roads.

**Q. Where is the front end of the steering rod carried?**

A. As a similar means of protection, the steering rod is frequently carried over or above the front axle, so that the axle will protect it. Even when the design of axle, steering knuckle, and other parts necessitates this rod being below, it is placed as close as possible to the axle level, so as to get the maximum protection.

**Q. What is the function of the steering knuckle?**

A. It forms a pivot, or bearing, upon which the front wheel rotates; but, in addition, it forms the basis of steering, being capable of turning about a vertical (or nearly vertical) axis.

**Questions for Home Study**

1. Describe the complete steering mechanism of the Pierce-Arrow car.
2. Why is it better to steer with the front wheels than with the rear wheels?
3. Tell in detail how a worm and sector mechanism works.
4. Describe the working of a worm and nut device. Is it better than a worm and gear and if so, why?
5. How is the Gemmer steering gear adjusted (a) for wear of the worms; (b) for looseness of the steering wheel? How is it lubricated?
6. Describe the Hindley worm. What are its advantages; disadvantages?
7. Select and describe one form of steering-wheel construction.
8. How would you adjust a steering rod for (a) length; (b) wear?
9. Tell the advantages and disadvantages of the various possible positions for the cross-rod; for the steering rod.

## FRONT AXLES

**Q. What are the usual front-axle classes?**

A. Eliminating freak forms, axles are generally divided into five classes: Elliott; inverted or reversed Elliott; Lemoine; front drive; and fixed axle, or fifth wheel, form.

**Q. What is the nature of the Elliott front axle?**

A. The Elliott form has the end of the axle in the form of a jaw, or Y, with a bearing above and one below the steering knuckle. The latter fits in between the two parts of the jaw, or Y, and consequently has a single central bearing.

**Q. How does the inverted Elliott differ?**

A. In the inverted, or reversed, Elliott form, the axle end is made with a single central bearing, while the knuckle takes the form of a jaw, or Y, and has the two bearings, one above and one below the axle end.

**Q. Which of these two forms is the better?**

A. There is little choice, but what there is seems to favor the Elliott form because it gives a stiffer and better bearing in the axle end, which is generally a good size rigid member. In fact, the axle ends can be made large enough in this form to have ball, roller, or other anti-friction bearings. This is not true with the reversed form.

**Q. How is the Lemoine axle constructed?**

A. The steering knuckle and its pivot are integral and form a letter L. The axle end is plain and forms a single bearing on the upper end of the steering pivot. In the regular Lemoine form, the L has its vertical leg extending upwards, and the axle is on top of the knuckle, so to speak. As constructed in United States the vertical leg of the L is turned downward, so that the axle is below the knuckle

**Q. What are the advantages of this form of construction?**

A. Both axle end and knuckle are simplified and can be constructed more cheaply. Moreover, the complete axle can be assembled or disassembled more readily and quickly. Some consider that this type has a nicer, cleaner appearance and thus improves the front of the car.

**Q. What is the disadvantage of the Lemoine type?**

A. The principal disadvantage of the Lemoine axle, ascom pared with other forms, is the difficulty of suitably handling the bearing loads. The ordinary axle has separate radial-load bearings and thrust washers or thrust bearings. In the Lemoine the axle-end bearing must handle both radial and thrust loads, as well as road shocks.

**Q. What are the usual axle materials?**

A. Modern practice restricts front axles to hand- and drop-forged steel, to tubular centers with forged ends, and to pressed steel. The latter is little used, however. Cast steel and manganese bronze as well as wood, have been used.

**Q. What are the usual axle bearings?**

A. Ball, roller, and plain bearings are widely used. For the sake of simplicity and compactness, the steering-pivot bearings are often plain, while the wheel bearings on the knuckle end are about evenly divided between ball and roller. Thrust bearings are about evenly divided between plain steel bearings with bronze washers, on the one hand, and with ball bearings, on the other.

**Questions for Home Study**

1. Describe a good method of truing front wheels.
2. How would you determine that front wheels were out of alignment?
3. Describe in detail the (a) Overland front-axle; (b) the Christie; (c) the Marmon.
4. How are axles lubricated, with reference to (a) wheel bearings; (b) steering pivots; (c) thrust washers or thrust bearings?
5. What are the disadvantages of cast front axles?
6. Are ball bearings better than roller bearings for front-axle pivots and if so, why?
7. Describe in detail the process of straightening a bent front axle. Would you use a template and if so, why?

## FRAMES

**Q. What is the need for a frame in an automobile?**

A. Every automobile needs a frame, stiff and strong enough to support all the units for power development and use, down to the springs.

**Q. Is there any radical difference between pleasure-car and motor-truck frames?**

A. None, except that the truck frame must carry a much heavier load and, therefore, needs to be stiffer and stronger and that it must cost less relatively, thus necessitating a form or shape which is cheaper to construct.

**Q. What materials are used for frames?**

A. Principally steel and wood. Steel is divided into rolled, used mainly for trucks; and pressed, used for pleasure cars and for the smaller trucks, or delivery wagons. Wood is divided into plain straight wood, laminated wood, and wood used as a filler for steel.

**Q. Is wood used at all widely?**

A. No. With the exception of Franklin, using laminated wood, and of a few light cars and light trucks which have a wood filler inside of a pressed-steel frame, wood is used very little.

**Q. Is steel tubing used for frames?**

A. Frames are no longer constructed entirely of tubing, although this has been tried, but some designers use tubular cross-members for the support of the engine, the transmission, and other units.

**Q. Is structural steel widely used?**

A. For pleasure cars very little, if at all; for trucks quite freely, but in gradually decreasing quantity. Frame makers are producing better and cheaper frames of pressed steel each year, gradually eliminating any and all arguments in favor of rolled or structural steel.

**Q. What is a frame "kick-up"?**

A. When the rear end of a frame otherwise fairly straight and level is bent sharply upwards from two or three to as much as ten inches, beginning just forward of the rear axle and carried out to the rear end of the frame on this higher level, this whole raised rear end is called a kick-up.

**Q. What is the purpose of a kick-up?**

A. It lowers the central part of the chassis relatively, thus giving a lower step, incidentally lowering the center of gravity and making the car safer. It raises the rear end to give adequate rear springing.

**Q. What is the shape of the modern frame, in plan?**

A. It is gradually assuming a considerable taper. Originally, the frame formed a rectangle, with straight side members. Then it was found advantageous to narrow the front end to give more room for the front wheels to turn and thus allow a shorter turning radius. As this had the additional effect of shortening the engine-supporting arms, the makers were able to eliminate the sub-frame, with a saving of expense and weight. Finally, the width needed for modern touring car rear seats gradually widened out the rear ends of the frame, while the narrowing at the front became so great as to put a weak spot in the frame where its greater load had to be carried. It

then became a logical step to make the frame taper from front to rear continuously, with straight sides. This is the form which all frames are assuming now.

**Q. In what other ways do modern frames differ?**

A. The rear cross-member is being eliminated very widely, as is also the front cross-member, so the triangular-shaped frame is not closed at either end. Formerly, the depth of the frame was pretty much the same from front to rear, but now this tapers very materially from the front up to the middle and then down again at the rear. A good stiff typical frame would be perhaps $2\frac{1}{2}$ inches to 3 inches deep at the front, 6 inches deep in the middle, and perhaps $2\frac{1}{4}$ inches to $2\frac{3}{4}$ inches deep at the rear. In short, except for perhaps 20 to 24 inches of length right in the middle, the frame depth would differ continuously.

**Q. What is the advantage of varying the depth so much?**

A. It eliminates every pound of excess weight, putting much metal where there is heavy load and severe stresses and little metal where the load and the stresses are light.

**Q. Is this form of construction more expensive?**

A. No. The art of pressing the frame out of sheet steel has been developed through large quantity production to such an extent that a frame of this type, with a constantly varying depth, costs no more than a straight frame cost four years ago.

**Q. Does this form give the repair man more to do?**

A. No. On the contrary, frames give less trouble in the way of sagging, breaking, or cracking than ever before. The frame troubles of today are mainly due to poor or light design, in an effort to lower weight too far, or to accidents.

**Q. What has been the effect of cantilever springs on frames?**

A. One effect of cantilever springs for rear use has been to eliminate the rear cross-member, as spoken of previously. Another effect has been to continue the deepest section back quite a few inches to the point of support of the front end of the cantilever.

**Q. Is the trussed, or latticed, frame widely used?**

A. No. Only by one or two makers, although a few heavy cars have a truss rod below the main frame to add stiffness and strength. The trussed, or latticed, frame is a new departure in frame design.

**Q. What are the noticeable tendencies in frame construction, other than those already mentioned?**

A. The use of heavier frames, that is, heavier sections of metal, deeper side members, and general stiffening is being accomplished without much gain in weight, owing to the better distribution of the metal. The combination of other units, as steps, step supports, and fenders with the frame is being worked out, this being one of the tendencies in construction. The general carrying of spare tires at the rear is having an influence, but there seems quite a tendency to construct the body so as to enclose the tires, which, if carried out, would change this.

**Questions for Home Study**

1. How would you repair a sagged frame, if sagged at (a) front end; (b) center; (c) rear end; (d) cross-member?
2. Describe the method of welding a cracked frame by the oxy-acetylene process.
3. Describe the following frames in detail: (a) Stearns-Knight; (b) Marmon; (c) Fergus.
4. How is the Franklin wood frame built up?
5. How is what is called an "armored frame" made?
6. Tell how to remove and replace an underpan.
7. What material is usually used (a) for a truck frame; (b) for a light pleasure car; (c) for a heavy touring car?
8. Give the advantages and disadvantages of pressed steel for frames.

## SPRINGS AND SHOCK ABSORBERS

**Q. What is the need for vehicle springs?**

A. To support the load in a flexible manner so that the jolts and jars of the road will not be transmitted to the passengers or load. In addition, a flexible connection between the power plant and the road wheels is needed.

**Q. How many recognized different types of spring are in use?**

A. Seven; all of which are made and used in all sizes and qualities for all kinds of load.

**Q. What are these seven types?**

A. The semi-elliptic, the full elliptic, the three-quarter elliptic, the platform, the cantilever, the quarter elliptic (or half semi-elliptic, as it is sometimes called), and the coil. All but the last three also are made with scroll ends, which alters the general appearance without altering the type of action.

**Q. What is the shape of the semi-elliptic?**

A. This form has a slight bow upwards, the two ends being slightly higher than the middle. The middle is attached to the axle and the ends to the frame, and when load is applied, these ends come down, flattening the spring so that it approaches a straight line.

**Q. Describe the full-elliptic spring.**

A. This form has the shape of two semi-elliptics, one inverted and set on top of the other. This gives it the appearance of an elongated letter O with points at the ends. The lower half is attached to the axle and the upper half to the frame, and loading tends to bring the two halves closer together, flattening the O still farther.

**Q. What is the form of the three-quarter elliptic spring?**

A. This consists of a flat lower semi-elliptic member and a highly curved quarter-elliptic upper member, the two being joined by means of a shackle. With the exception of the difference in curvature of the two parts and the use of the shackle to join them, this has the appearance of a full elliptic with the upper forward quarter cut away. When loaded, both members give slightly, the upper quarter more than the lower half. The shackle gives a considerable difference in this action from that of the full-elliptic.

**Q. What is the platform spring like?**

A. This spring consists of three semi-elliptics joined together at the ends so as to form three sides of a rectangle. The two sides are fastened, respectively, to the axle at the middle of each, to the frame at their front ends, and to the third spring at the rear ends. The rear spring is inverted and its center is fastened to the center of the rear end of the frame, while its ends are shackled to the rear ends of the two side springs. This makes a combination in which the normal semi-elliptic spring action is modified somewhat by the inversion of the rear cross-member and by the use of shackles at the ends of all three. While popular three or four years ago, it is now going out in favor of the three-quarter elliptic.

**Q. What is the cantilever spring like?**

A. It consists of an inverted semi-elliptic fixed or shackled to the outside of the frame at the front end, hinged or pivoted slightly forward of its center to the outside of the frame, and having its rear end attached to the upper or lower surface of the rear axle. It is used in greater lengths than any other form of spring and is very popular.

It is the most simple spring now in use and is said to give the easier riding of all.

**Q. What is the quarter-elliptic spring like?**

A. This is simply what its name indicates, one-half of a semi-elliptic or one-quarter of a full-elliptic. Its front end is fixed to the frame outside, and the rear end is shackled or allowed to slide on the rear axle. It is generally inverted. In reality, it is a cheap substitute for the cantilever or inverted semi-elliptic, this use being allowable because of the light weight of both car and load.

**Q. Is this used in any different way?**

A. Sometimes a pair of these is used, one above the other, with the idea of doubling the resistance or rather of giving equal resilience with but half the movement.

**Q. What is meant by underslinging?**

A. When this refers to frame, the entire frame is placed below the springs. This has gone out of use. When referring to springs, this means placing the spring below its support, as below the rear axle. This construction lowers the frame and center of gravity by the thickness of the spring plus its seat plus the diameter of the rear axle, sometimes amounting to a total of five inches. It is growing rapidly in popularity.

**Q. What is the purpose of a shock absorber?**

A. To absorb the small vibrations while the spring cares for the large ones. It generally takes the form of any auxiliary spring or friction device.

**Q. What are the general classes of shock absorber?**

A. Coil spring, flat-plate spring, friction plates, compressed air, and a few hydraulic (or liquid) forms.

**Questions for Home Study**

1. How are springs lubricated (a) as to leaves; (b) as to shackles?
2. How are the spring leaves separated for lubrication?
3. Describe a method of getting home with a broken rear spring.
4. Why do racing cars have their springs wound with rope or cloth?
5. Describe the following car springs in detail: King; Winton; Ford.
6. How do electric car springs differ from those of gasoline cars?
7. What are the standard spring-plate widths?

**SECTIONAL VIEW OF PACKARD "TWELVE", SHOWING POWER UNIT AND TRANSMISSION TO REAR AXLE**

*Courtesy of Packard Motor Car Company, Detroit, Michigan*

# GASOLINE AUTOMOBILES

PART VI

## FINAL-DRIVE GROUP

### REAR AXLES

#### TRANSMISSION

**Units in the Final Drive.** Generally speaking, the transmission is located in the middle or forward end of the chassis. When this is the case, the final drive begins right at the rear end of the transmission. The units back of the transmission, then, would be a universal joint; a driving shaft; possibly another universal joint; the final gear reduction; rear-axle shafts and enclosure; the differential; the torque rod, or tube, or substitute for it; the wheels; the brakes; the tires; and other smaller units.

Even when the transmission is placed on the rear axle, this general layout is changed little, and the transmission, which has been covered in detail previously, is not considered again. In the case of a chain drive, which is still used on one pleasure car or perhaps two, on a number of small trucks, and on a large number of large trucks, this layout is changed considerably. In the large trucks, the transmission in perhaps 90 per cent of all cases would be in a unit with the jackshaft, which means that for consideration in the final-drive group there would be only the driving shaft to the transmission; the joint or joints in it, if any; the chains and the method of adjusting them; the rear axle and wheels; the brakes; the differential, of necessity becoming a part of the transmission; and the jackshafts.

To make this clear and point out the various units, it will be noted in Fig. 430 that it is a unit power plant. Directly back of the transmission is the first universal joint, driving through the hollow propeller shaft to the rear axle, in front of which is the second universal joint. The rear-axle group includes the axle shafts, differential gears, final gear reduction, gear housing, and the wheels. The torque reaction of the drive, to be explained later, is taken by the torque rod, marked in the drawing, which connects the rear axle to the under

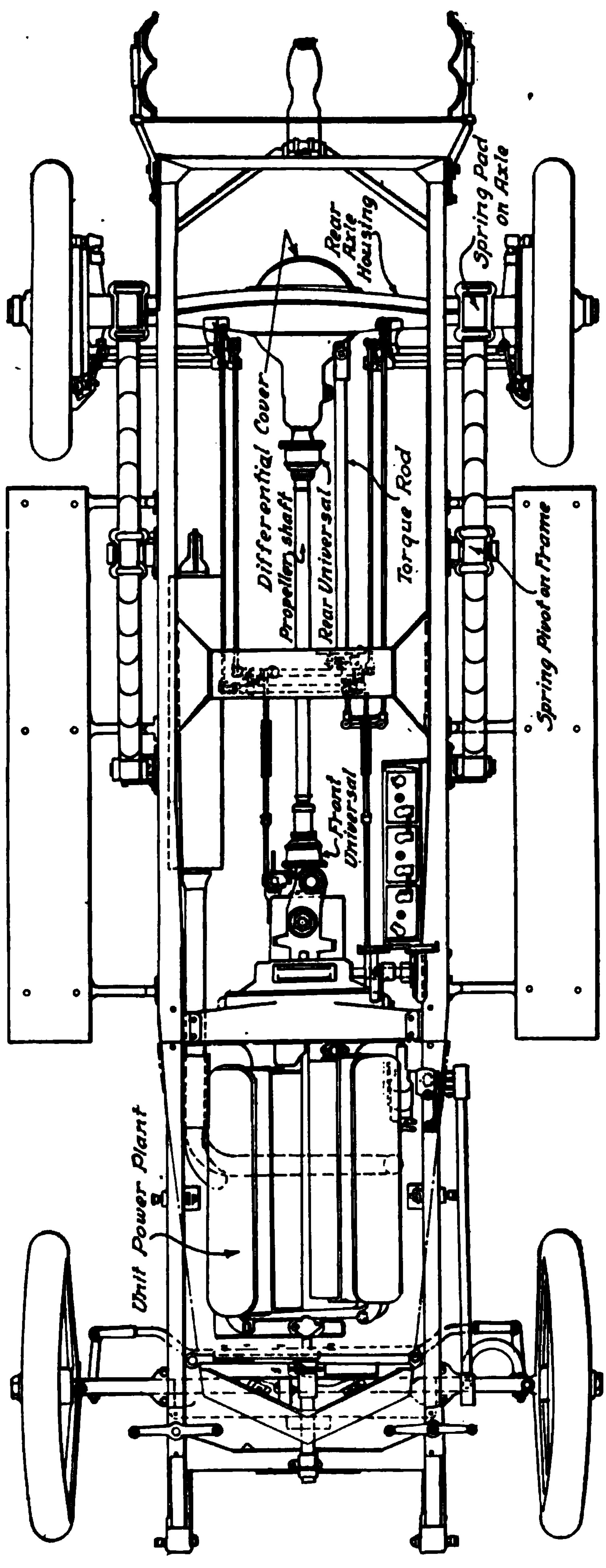



Fig. 430. Layout of Units in Final-Drive Group
*Courtesy of Federated Motors Company, Indianapolis, Indiana*

side of the stout frame cross-member in front of the axle.

**Universal Joints.** The purpose of taking up the universal joints—it can be seen from the drawing—is to show how the rear axle rises and falls or moves sidewise in either direction without making any difference in the transmission of power to the axle. When joints are used at other points, the purpose is generally to take care of any lack of alignment, but here the purpose is to transmit power at an angle.

The transmission of power at an angle is effected by constructing the joint so that it can work at any angle. Usually, this is done by constructing the central member in the shape of a cross, with four projecting arms or pins, all in the same plane. The ends of the two shafts are made in the form of forks, or Y's, and are set at

right angles to each other, that is, the forks are laid in planes which are at right angles. The fork on one shaft is fastened to a pair of diametrically opposite pins, while the fork on the other shaft is fastened to the other pair of diametrically opposite pins. Each shaft is able to turn on its pins about a line through the center of both. As these two lines are in planes which are at right angles to one another, but intersect at a common center, movement is possible in either plane, or by combination movements of both, in any direction.

**Slip Joints.** In many situations, a real universal joint is not needed, since the parts are not actually free to move in all directions; but what is needed is slight freedom up and down or sidewise combined with possible fore-and-aft movement. In such cases a slip is used, the name giving the idea of a joint which allows one shaft to slip, or slide, inside the other. The general construction of slip joints varies. Sometimes a round gear is fastened to the end of one shaft; this gear has a fairly large diameter and many teeth, with the teeth chamfered to an unusual extent—almost rounded, in fact. An internal gear of the same size and number of teeth with similarly rounded profiles is meshed with the hollow gear of the other shaft. Both gears have unusually wide faces. This combination gives an action that is almost universal, and also allows lateral sliding of perhaps ½ inch.

The second form of slip joint consists of a squared shaft and square enclosure. The end of the shaft has a member split along a central line attached to it; the exterior approximates a round of large diameter, but the interior is machined to a perfect square, one-half in each part of the split member. Attached to the end of the other shaft is a member machined to an exact square, but slightly rounded in a fore-and-aft direction. The square will drive, no matter in what part of the housing it is located, so that considerable fore-and-aft sliding is possible. In addition, the rounded surface of the square gives an approximate universal effect. The split housing is used to make assembling and disassembling easier and much quicker. Sometimes such a housing is put on the end of each shaft, the connecting member being made in the form of a dumb bell, but with two square ends—one to work in each squared-out housing. In this way the effect of a full universal joint with the fore-and-aft sliding is obtained at less cost, and with easier assembling and disassembling as extra advantages.

Occasionally a square joint is constructed as simple and small as possible, in which case the housing is not split and the shaft end is not rounded. This gives a simple square which drives through a simple squared-out hole. In this case there is no universal action, but simply lateral or sliding freedom.

**Other Flexible Joints.** To get away from the complication of the universal joint and yet give practically the same results, many other forms have been produced. A very thin disc of tempered steel, with the two shafts bolted to the two opposite sides of it, has been used. The metal will bend and give enough to allow considerable angle of drive. Later forms of the same joint use leather in several thicknesses, the leather being bolted up to the two shafts in the same way. A joint of this kind, consisting of several layers of fabric which have been fastened together in laminations until a disc of fair thickness, say ½ to ¾ inch, has been built up, is shown in Fig. 431. Then the leather is cut round and drilled for the bolts. In this form, six bolts is the preferred number, three for each shaft end; they are in a three-armed spider fastened to the end of each shaft, as the figure shows. These newer forms are usually convenient for the repair man, for they allow breaking into the main shaft by the simple removal of the three bolts (or two as the case may be). By taking out the bolts at each end of such a shaft, the shaft itself can be removed, leaving the other units in the chassis ready for immediate removal, according to the needs of the repair job.

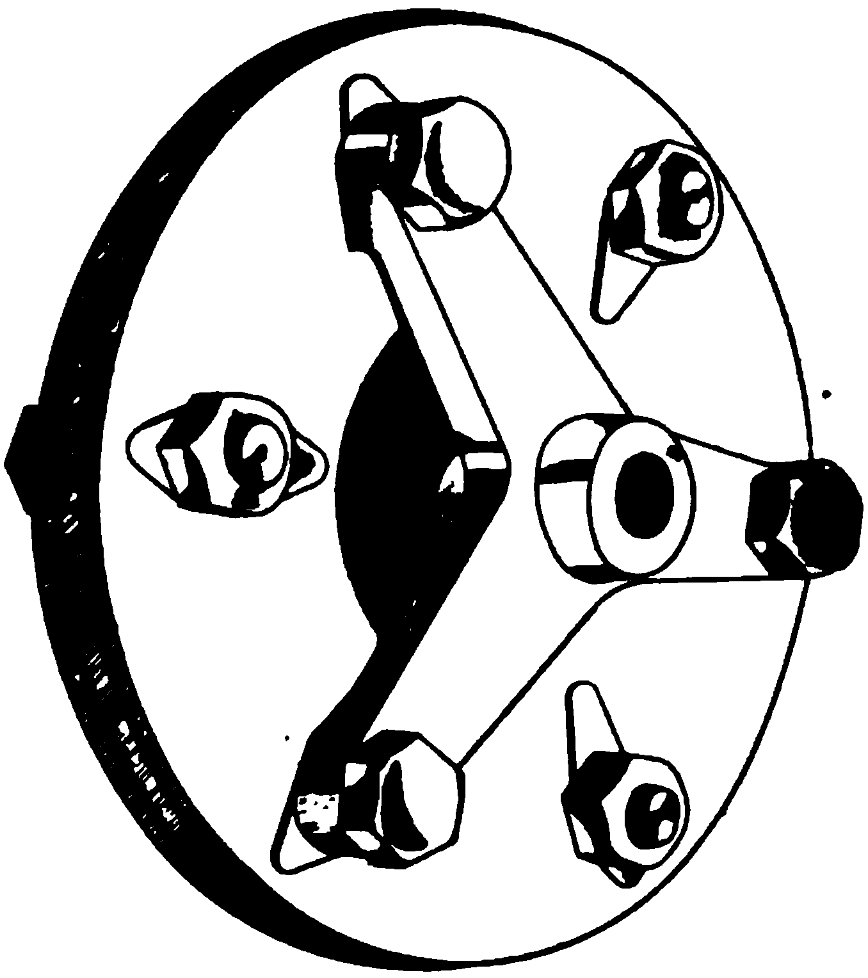


Fig. 431. Laminated Discs Forming Flexible Shaft Coupling
*Courtesy of Thermoid Rubber Company, Trenton, New Jersey*

**Types.** Possible types of final drive, from the gear box to the rear axle and the driving wheels or from the motor to the gear box—in case this is mounted on the rear axle, as is not uncommon practice—are practically limited, in cars of sound design, to shaft and double-chain constructions.

*Shaft Drive.* In its usual form, shaft driving in an automobile involves simply a propeller shaft interposed between the rear axle and a revolving shaft in the car above the spring action. There is some provision for taking the torque of the shaft and of the axle so that they shall maintain their proper relative positions.

In Fig. 432, a typical short driving shaft with its two universal joints is shown. This is such a shaft as would be used in the car shown in Fig. 430, except that the latter is a long wheel-base car with its transmission in a unit with the motor and clutch and thus, far forward. This combination necessitates a very long propeller shaft. The one shown is actually from a car having a short wheel base, with the transmission located amidships. This is a combination which calls for a fairly short propeller shaft.

The short shaft, shown in the figure, is a solid shaft. The modern tendency toward lighter weights is being worked out in the case of

Fig. 432. Ordinary Driving Shaft of Solid Form with Two Universal Joints

propeller shafts, and many are now made hollow. By making the diameter slightly larger and having a large central hole, unusually light weight is obtained with all the strength of the solid form. In addition, the larger diameter hollow shaft has more rigidity than the small diameter solid form, and in many of the modern cars without torque or radius rods, unusual rigidity of the driving shaft is necessary. Other forms have been used for the driving shaft, but they come more or less in the freak class. About two years ago, a car was brought out with a spring, or flexible, shaft, which consisted of a rectangular member of considerable height, but fairly thin. The idea was not only to transmit the power of the engine, but to do it in a flexible manner, that is, the shaft was supposed to absorb all the sudden changes, such as quick acceleration or quick braking. At the same time, one of the electric-car makers brought out a chassis with a square driving shaft of very small size. This served the same purpose as the flexible

shaft only in a different way; its two ends, setting in square holes formed two sliding joints without further machining.

Fig. 433. Ford Final Drive, Differential, and Axles

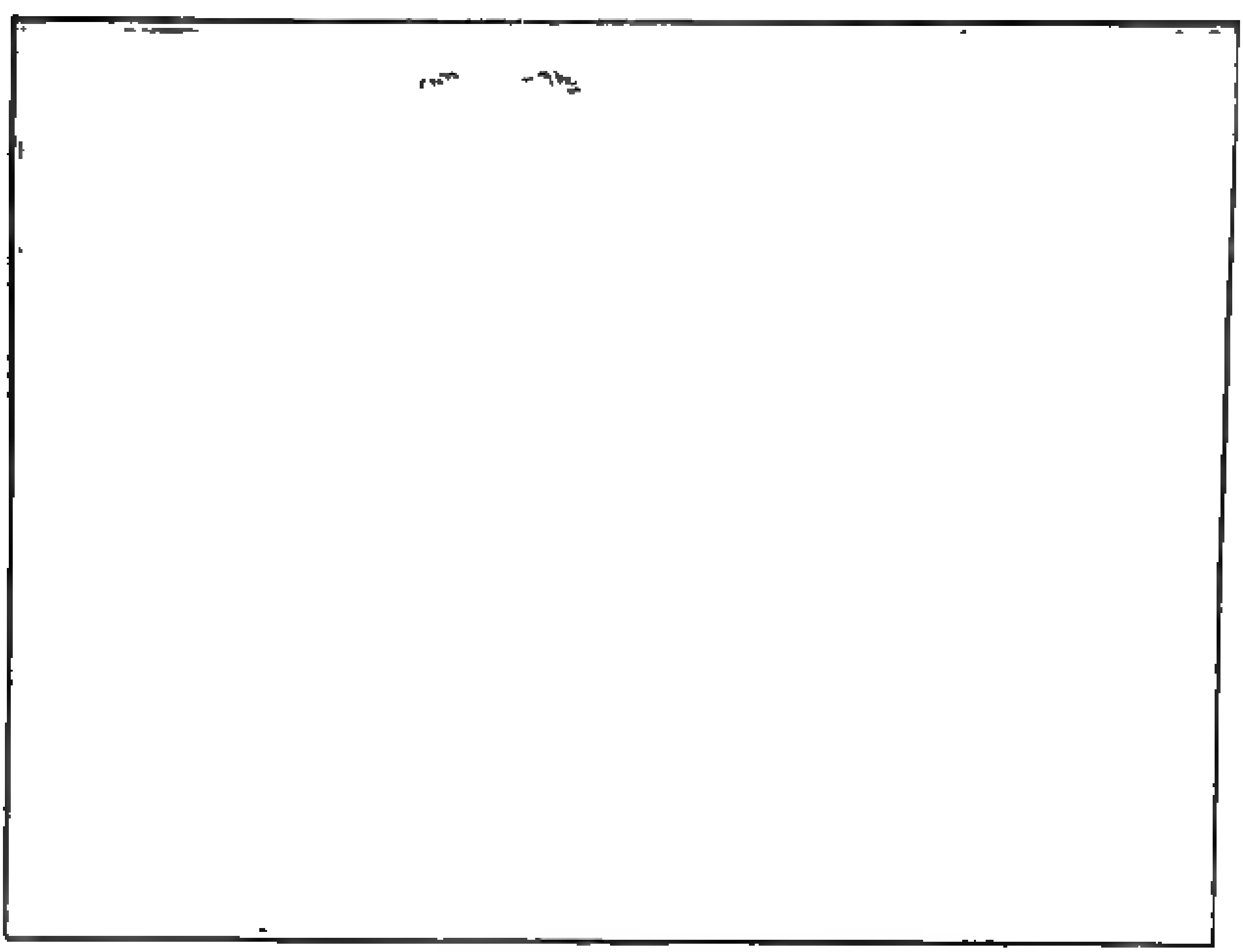


Fig. 434. Worm and Gear for Rear Axle, Showing Upper Position of Worm
*Courtesy of Timken-Detroit Axle Company, Detroit, Michigan*

An objection to the shaft type of drive is that the reaction of the revolving shaft tends to tilt the whole car on its springs in a direc-

tion opposite to that in which the shaft is turning. In some cars, this is counteracted by the use of slightly heavier springs on one side. The advantages of the shaft drive are the complete enclosure of all working elements, with their consequent protection from dirt and the assurance of their proper lubrication.

The final drive of the Ford automobile, in which the end of the propeller shaft is shown at $A$, together with the bearings in which it revolves, the pinion by which it drives the car, the axle, the differential, and the bearings of the floating inner elements of the axle is illustrated in Fig. 433.

The shaft drive does not necessarily include the use of bevel gears for the final reduction at the rear axle; in fact, almost any form of gears may be used. In one well-known shaft-driven commercial car, the final gears consist of a pair of plain spur gears, while on the shaft of the second of these gears is a pair of bevels.

Fig. 435. Spiral Bevel Gears—a New Noiseless Type for Rear Axles
*Courtesy of Timken-Detroit Axle Company, Detroit, Michigan*

As soon as the bevel gear final reduction disclosed its limitations and disadvantages, designers started to displace it. One of the earliest forms of gear used for this purpose was the worm, an example of which can be seen in Fig. 434. This figure shows the worm placed above the wheel, but the lower position, which is also used, has the advantage of copious lubrication. In the form shown, the wheel must come directly beneath the worm so that the differential may be set inside of it.

The worm is usually more suitable for slower moving vehicles which have a large reduction of speed between engine and rear wheels, that is to say, it is peculiarly fitted to electrics and motor trucks of all

sizes, on which it is finding wider and wider use. On pleasure cars of the average size and type where a speed as high as 50 m.p.h. or higher is expected by all concerned, it has not been found suitable and consequently is not being used.

A later form, which is designed to replace the straight bevel, is the spiral bevel. This is primarily a bevel gear with spiral teeth, the

Fig. 436. Typical Roller Chain

idea being to incorporate in the bevel gear the advantages of the spirally shaped worm tooth, without its disadvantages. As Fig. 435 shows, this makes a very compact and neat arrangement, the differential fitting within the larger gear in the same manner as with the worm.

*Double-Chain Drive.* The use of double chains, by which the driving wheels of an automobile are driven from a countershaft across the frame of the machine, is a practice possessing a number of advantages. But because of the noise and quick wear with badly

Fig. 437. Typical Silent Chain

designed chain drives and the difficulties of completely enclosing the driving mechanism, chains are not now as popular as formerly. Nevertheless, the elimination of universal joints working through large angles and under heavy loads, the avoidance of heavy weights carried on rear axles without spring support, the lowering of the clearance by the differential housings, etc., are very real objections that the double chain avoids.

For trucking and other heavy service, chains are still commonly in use, and it is the belief of many that a better understanding of their

merits and the means of securing these merits in positive and permanent form will result in their more general use.

A typical roller chain of the type most used for automobile drives is illustrated in Fig. 436.

Silent chains, of the types illustrated in Figs. 437 and 438, possess certain points of superiority over roller chains and are therefore coming increasingly into use for camshaft drives, in gear boxes, etc., and there is some possibility that they will find more extensive application to final drives than at present.

The action of a silent chain is illustrated in Fig. 438, in which it is seen that as the chain links enter the sprocket teeth the chain teeth at the same time close together and settle in the sprocket with

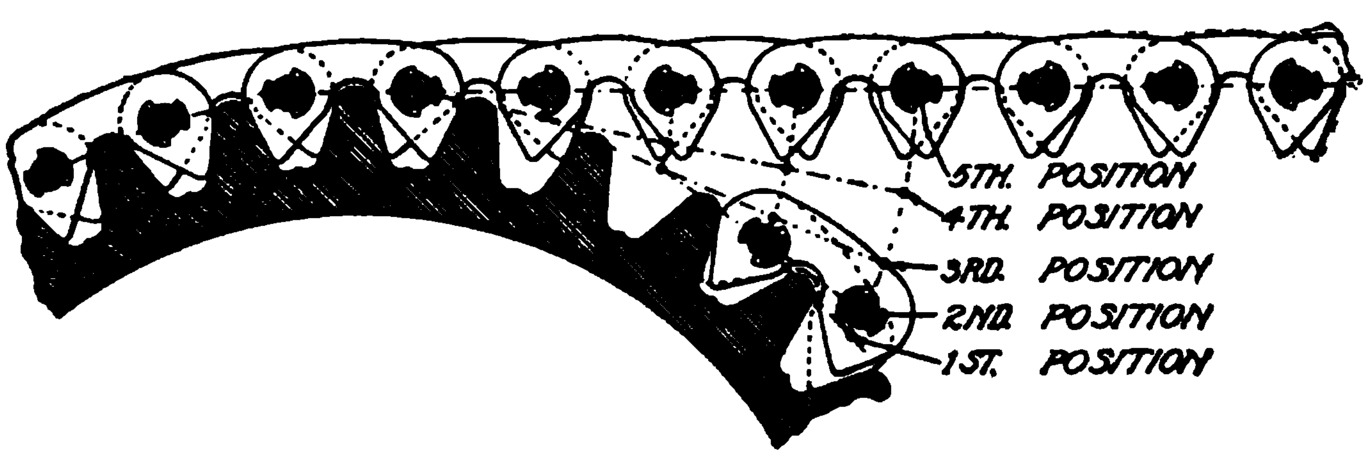



Fig. 438. Action of Silent Chain and Sprockets

a wedging action that causes them to be absolutely tight, but without any more binding than there is backlash.

To keep silent chains from coming off sidewise from the sprockets over which they run, it is customary to make the side links of deeper section than the center links, as is illustrated in Fig. 437. Another successful scheme is grooving the sprocket to receive a row of special center links in the chain, which are made deeper than the standard links.

At present, only one American pleasure car, the Metz, has final drive by means of silent chains. This is a small car with a friction transmission, the drive from the ends of the cross-shaft being by enclosed silent chain to each rear wheel.

**Torque Bar and Its Function.** It is a well-known fact that action and reaction are equal and opposite in direction, so that if a gear is turned forcibly in one direction, say clockwise, there is a reaction in the opposite direction, or counter-clockwise. This is the simple basic reason for a torque bar, or torque rod, on an automobile. It is needed with any form of final drive, but it takes different forms, according to

the type of gear used. The bevel and spiral bevel used on 88 per cent of the 1917 cars are explained in detail as follows: Fig. 439 shows the rear end of a typical pleasure-car chassis. The engine is rotating clockwise, and so is the driving shaft *A*, as shown by the arrow. The shaft turns the pinion *B* in a clockwise direction, which rotates the large bevel *C* so that its top turns toward the front of the car. The bevel *C* turns the rear axle *D* and the rear wheels (not shown) in the same direction; so the car moves forward.

In addition to the gear *C* and shaft *D* turning easily in the axle housing *E*, there is an equal and opposite reaction which tends to keep them stationary, while the bevel pinion *B* and driving shaft *A* tend to rotate around the rear axle as a center in a counter-clockwise direc-

Fig. 439. Diagram to Show What Torque Is and Why Torque Rods are Necessary

tion, as shown by the diagram. If the rear axle were held firmly so it could not rotate, and there was nothing to restrain the bevel pinion and shaft, this could easily happen. However, since we do not wish this to happen, a means is provided to oppose this action and prevent it from happening. Since the turning force which makes the shaft rotate is called the torque, this rod, bar, or tube, whatever its form, is called the torque member.

In the sketch, the torque member is marked *F* and is attached to the frame cross-member *G*, between a pair of springs, so as to cushion the shocks of sudden car or shaft movements. The force on this is the force which tends to rotate the driving shaft and pinion counter-clockwise, so that it works upward, as shown by the arrow. The frame prevents this and absorbs the force.

**Driving Reaction.** As has been stated, the power, or torque, of the motor is used to rotate the rear wheels. These stick to the pavement or road surface, so the car is really pushed forward. Since it is this pushing action which really moves the car forward, it is very interesting to note how this push is transmitted from the wheels and rear axle to which they are attached to the frame which carries the body and passenger load.

The transmission of the drive to the body is accomplished in one of three ways. The first form was the so-called radius, or distance, rod, which the shaft-driven car inherited from the chain-driven form. In the chain drive, these rods were a necessity and served a double purpose; they kept the driving and driven sprockets the proper "distance" apart for correct chain driving (hence their name "distance" rods), and they also transmitted the drive back to the frame. On the shaft-driven car, the distance function is not needed, so they are called radius rods. As shown in Fig. 440, they transmit the drive forward to the frame, thus propelling the car in the direction of the arrow, and they also keep the rear axle in its correct position.

Fig. 440. Diagram to Explain Driving Reactions Using Radius Rods

Fig. 441. Layout of Driving Reaction Using Torque Tube around Shaft

In lightening and simplifying the shaft-driven car, designers figured that three members for the torque and driving reactions were too many; so a design was worked out in which all three were combined into one, which is a form of tube surrounding the shaft. This made the member light but strong, and simplified the whole rear end. As shown in Fig. 441, the tube has forked ends at the front, which are connected to the frame cross-member in such a way as to absorb the torque reaction and also to transmit the drive. The method has the further advantage of needing but one universal joint, and that at the front end. Furthermore, it gives a correct radius of rise and fall for the rear axle, since the center of the combined torque and drive member is also the center of the universal joint in the driving shaft. In the form shown in Fig. 339 (radius rods not shown), the two different centers will be noted, the torque rod giving a greater radius than the shaft. Similarly, in Fig. 440 (where the torque rod is omitted for clearness), the rods give a longer radius of rear-axle movement than the shaft, which has a joint close to the axle.

Fig. 442. Arrangement of Driving Reaction When Hotchkiss Drive is Used

It will be noted that both these methods allow complete freedom of the rear springs, which may be of any form, and shackled at the front end if desired by the designer. In its newest and simplest form, the so-called Hotchkiss, or spring, drive has both the radius and torque rods omitted, the springs being forced to transmit both forces, as shown in Fig 442. In this case, the forward end of the rear spring must act as a rod, or lever, instead of as a spring, and must be fairly straight and stiff without a shackle, but firmly pivoted on the frame. In addition, the shaft must have two universal joints, as shown.

It must be stated, as a simple fact, that this last form is increasing rapidly and at the expense of the other two. On smaller lighter

cars it is gradually replacing all other forms. It has the advantages of minimum weight and fewer parts, and applies the driving force in a direct line to the frame, the same as the two radius rods do. On the other hand, it makes the springs serve a triple purpose, the demands on these for torque and drive transmission and absorption being such that the spring flexibility must be negligible, which makes the car ride hard. In addition, making the springs handle the three widely different actions puts additional stresses upon them, so that they are more likely to break. On the medium size and larger heavier cars, this construction is not gaining so rapidly.

## TYPES OF REAR AXLES

**Classification.** Rear axles may be divided into the following classes, distinguished according to the method of carrying the load and taking the drive: the form in which the axle carries both load and drive; the semi-floating form, carrying the drive and a small part of the load, the axle shafts not being removable without removing the wheels; three-quarter floating form, carrying the drive and a small part of the load, the latter being divided between the shaft and its housing, but with the shafts removable; seven-eighths floating form, carrying the drive but not the load, the arrangement of bearings to take the load being such that the wheel hubs do not rest wholly and solely upon the axle-casing end; the full floating form, in which the shaft does nothing but drive, and is removable at will without disturbing the wheel and wheel weight resting on the axle-casing end, which is prolonged for this purpose.

The seven-eighths floating type has been developed to meet the need which arose for a floating construction, in which the axle casing did not pass entirely through the wheel hubs. With the full floating form, any accident to the wheel, in which it was struck from the side, also damaged the casing, or tube, end. The result of this in nine cases out of ten was to make the removal of the wheel impossible, because the tube end, which projected through, was bent over. Moreover, repairing in such a situation called for a new axle casing —a very expensive proposition. Consequently, the seven-eighths floating form was developed to present all the advantages of the full floating form, with this serious drawback eliminated by a rearrangement of the parts which did not necessitate prolonging the axle

through the wheel hubs. Despite the facts, it did not gain as rapidly as the other floating forms, and now is almost out of use.

The three diagrams in Fig. 443 explain the types as well as words can. At the top is shown the full floating axle, the best but most expensive form. In the middle, the semi-floating axle, which makes the axle shaft do all the work—carrying load as well as transmitting power—is shown. At the bottom is the three-quarter floating form, which is really a combination of the other two forms and possesses a maximum of advantages with a minimum cost. The car weight is carried on the tubing, while the shaft drives and carries a portion of the side stresses to which the wheels are subjected, the quantity depending upon the construction of the bearings.

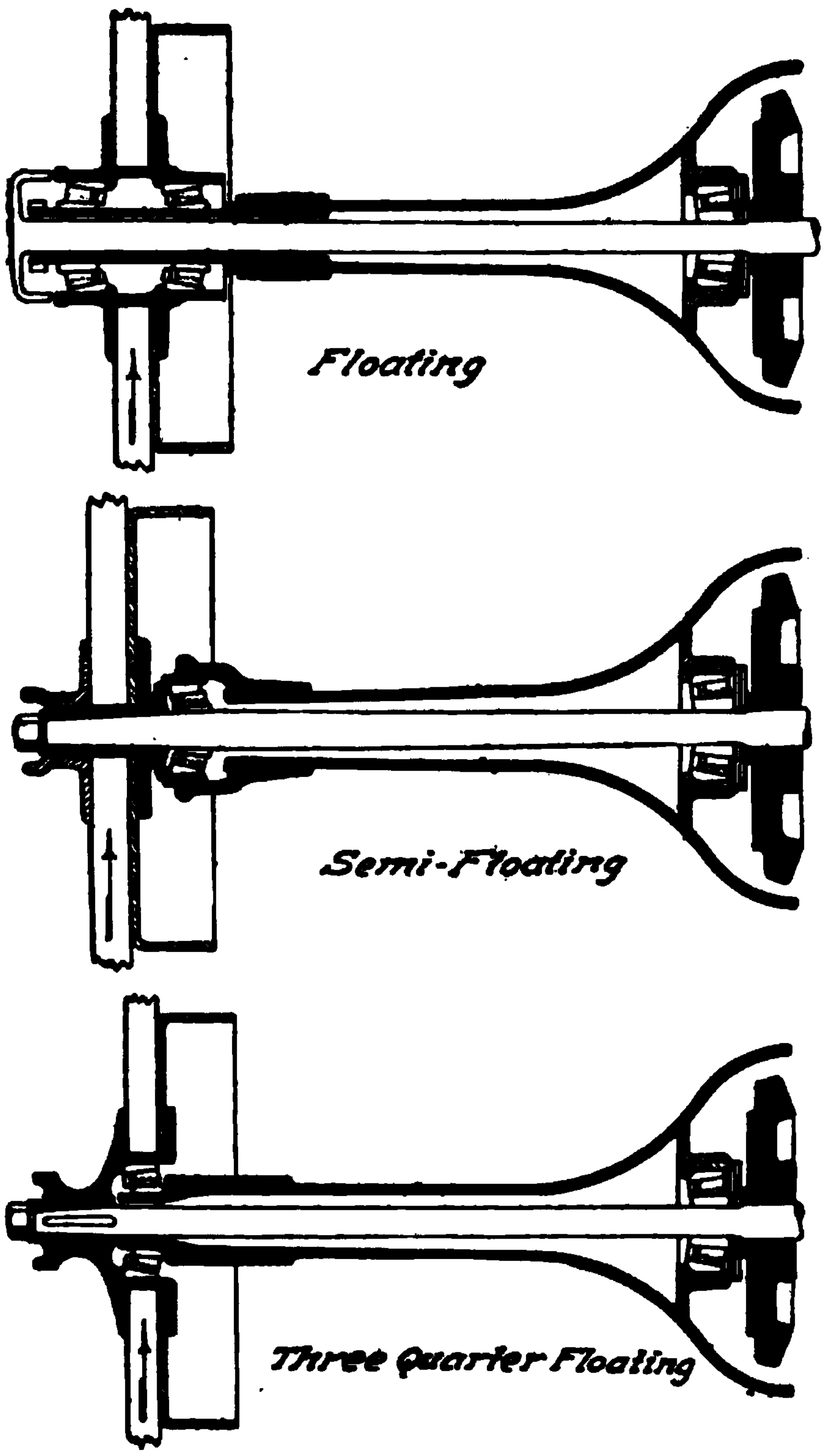


Fig. 443. Arrangement of Axle Bearings and Housing in Three Principal Forms of Rear Axle

Of the 1917 cars, practically 30 per cent (29.5) have the three-quarter floating rear axle, 25.5 per cent the semi-floating form, and 43.5 per cent the full floating form. In 1916, however, the three-quarter form was used in but 22.8 per cent; and in 1915 in only 18.5 per cent of the cars. These figures show how the three-quarter floating axle has been gaining constantly at the expense mostly of the floating form, the semi-floating form practically standing still for three years.

**Axle Carrying Load and Drive.** The type in which the axle carried both load and drive was a peculiar one and did not last long. In this form, the rear-axle shafts were exposed and carried the weight of the load at the spring seats, which were bushed to allow the shafts to turn within them. This made a place which was hard

to lubricate, and yet which was down in the dust and dirt, so that lubrication was a great necessity. All these causes, coupled with the fact that the axle carried both load and drive, caused its disuse.

**Dropped Rear Axle of Full Floating Type.** The dropped type of axle is not much used at present for cars of the shaft-driven type, the dropped part of the axle bed being used to hold the rearward-

Fig. 444. Rear Construction Embodying Dropped Type of Rear Axle

which the weight of the car as well as the weight of the load is carried on the I-section drop-forged rear axle, while the drive is transmitted from the transmission by the usual shafts, which carry no load. The cut shows the complete assembly above and the dropped axle below. The round ends of the I-beam axle are hollow, carrying the driving shaft through the central hole and the wheels on bearings which fit over the outside. The wheels will revolve on the bearings, even if the inner shafts and transmission be removed from the chassis.

Despite its manifold advantages, the expense of constructing an axle of this type—it is practically the same as that of two ordi-

nary axles, making the total cost double that of any other form—has worked to prevent its general use. In fact, it is not now in use in this country, as the maker has gone out of business.

A prominent French constructor, De Dion, utilizes a dropped rear axle, but, in this, the differential casing and gearing are suspended from the frame and drive down to the axle shaft by means of a pair of short inclined shafts with two universal joints in each, that is. the drive from the differential to the two wheels contains four universal joints. The inevitable loss due to the necessarily short inclined shafts and to the two joints in each has deterred other manufacturers from

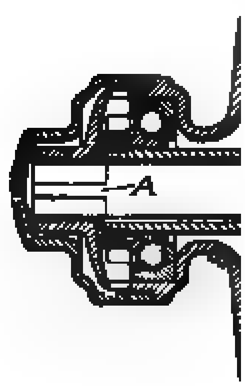



Fig. 445. Typical Ball-Bearing Differential

using this form, although a few makers—notably the Peerless Company—have inserted a pair of joints in the rear axle in order to give the rear wheels the same camber as the front wheels. As this necessitates inclined shafts, the joints are needed to connect the horizontal center part with the inclined ends.

**Clutch Forms in Semi-, Three-Quarter, and Full Floating Types.** The main point of difference in the various semi-, three-quarter, and full floating axles, aside from the principle of design which makes them decidedly different, is the clutch, by means of which the wheel is driven. In some cases, this clutch takes the form of a gear, with straight sides

and external notches, or jaws, to correspond with the teeth, but usually it is more of a claw type, the driving ends projecting inward from the point of attachment to the axle shaft. Another notable point of difference—and one which makes a huge difference in the cost —lies in the machining of these jaws, whether they are attached to the axle or machined up with it in one piece. The latter is considered better and stronger in every way, but, as it is much more expensive, it is used only on the best cars.

The driving clutch takes various forms, one of which is shown in the Studebaker axle, Fig. 445. In this type, the axle is a square rod acting within a square hole in the hubs. In the small detail at the upper left-hand corner the letter $A$ shows the square upon which the driving clutch is slipped. The spaces at the inner ends of this indicate the clutches, or jaws, which mesh with corresponding slots on the wheel hub and thus do the driving.

Fig. 446. Rear Axle, Showing Wheels Driven by Spur Gears

The dropped type of axles are neither all shaft-driven nor all chain driven. Fig. 446 shows one that is of the spur-gear driven type. The dropped axle bed $C$ is of tubular form, and the differential case is dropped down on and slightly back of the rear axle, as at $B$. From this case, two shafts $A$ $A$ extend out to the sides, driving the wheels through the medium of the spur gear $D$, which meshes with internal gears within the wheel hubs (not shown). This type of rear axle and drive is used on a number of the Fifth Avenue stages in New York City.

**Internal-Gear Drive for Trucks.** The spur-gear driven type just described is gaining rapidly for motor-truck use, because it has a number of important advantages. Besides carrying the heavy load on a member able to withstand any amount of overload, it materially lightens the power-transmitting portion of the axle, which is enclosed and therefore quiet. It is simple and inexpensive to construct and repair. Fig. 447 shows a section through one of these axles, which is

used on a very light truck of ¾-ton capacity. In this figure, it will be noted that the load-carrying axle is behind the power-transmitting shafts, consequently the former is straight. In Fig. 446, the load carrying axle is in front and consequently must be bent down at the center. This bend is a source of weakness.

**Full Floating Axle.** Fig. 448 shows a full floating axle, with the ends of the driving shafts projecting beyond the housing and carrying five jaws which mesh with five similar ones in the wheel hubs and thus drive the wheels. Unless the jaw end is welded on to the shaft, this makes a very expensive axle despite its many good points. Fig. 449 shows the rear construction of a car with full floating axle, with the brace below it for the purpose of strengthening the whole construction. The large diameter brake drums, shown close to the wheels, are made of pressed steel and are united to the axle tubing, which is also united to the differential housing, so that the whole forms one large and continuous piece, except where the differential unit bolts on one side and the cover on the other. Note that the shaft

Fig. 447. Sectional Drawing through Internal-Gear Drive Axle of Three-Quarter Ton Capacity
*Courtesy of Russell Motor Axle Company, Detroit, Michigan*

has the driving clutches machined as an integral part, and that removing the two shafts for a few inches makes it possible to unbolt

Fig. 448. Example of Full Floating Type of Axle

Fig. 449. Timken Full Floating Rear Axle, Showing Differential Removed
*Courtesy of Timken-Detroit Axle Company, Detroit, Michigan*

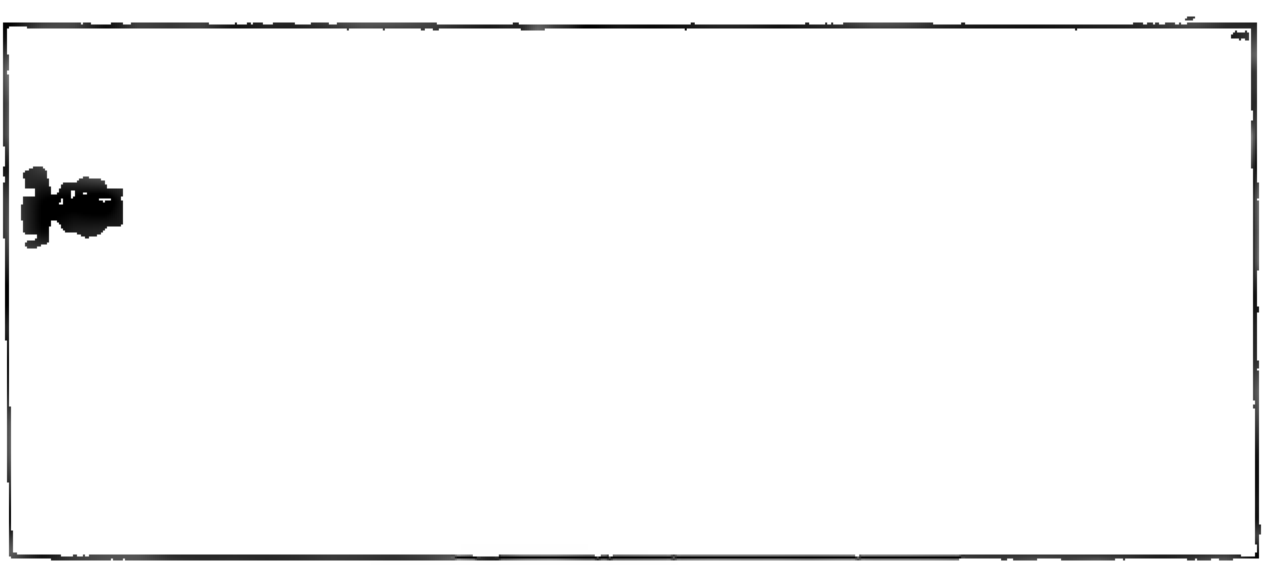


Fig. 450. Timken Full Floating Rear Axle with Spiral Bevel Gears

and remove the entire differential unit. For the sake of comparison, Fig. 450 shows an axle which differs from Fig. 449 only in having spiral bevels substituted for the ordinary straight-tooth bevels. In

Fig. 450, the differential unit is removable in the same manner a in Fig. 449. One of the axle shafts, with its integral driving clutches and the differential cover are shown below. Note the two plugs i the cover; the upper one is for filling the case with lubricant, while th lower plug acts as a level indicator. When it is opened, heavy oi or oil and grease combinations are put in the filling plug above unti the lubricant begins to flow out of the lower opening.

**Three-Quarter Floating Axle.** An interesting study in rear axl design is seen in Fig. 451. This axle has a number of points in whic

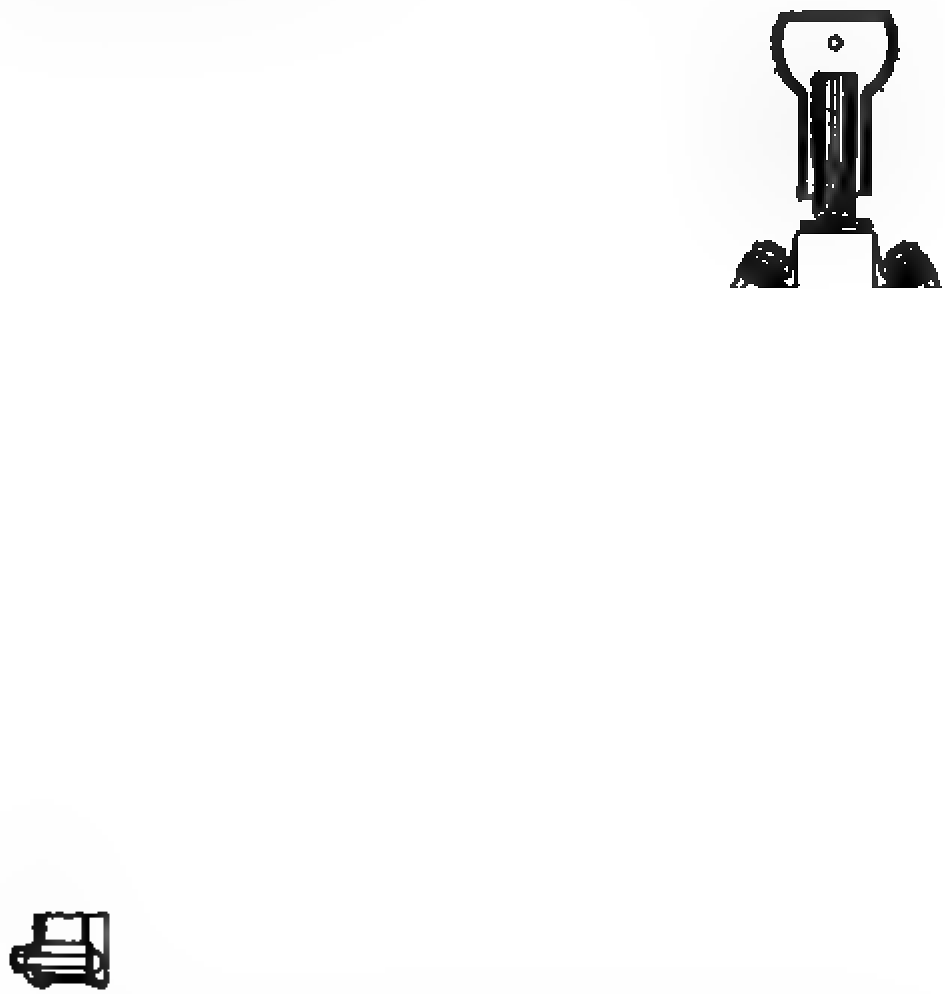


**Fig. 451. Partial Section through Rear Axle of Case Car, Showing Construction**
*Courtesy of J. I. Case T. M. Company, Racine, Wisconsin*

it differs from previously described forms. It is of the three-quarter floating type. Note the enclosure of the driving shaft and the splines at its forward end for the universal joint, also the housing for the joint forming the torque member. The small roller bearing for the spigot end of the driving shaft beyond the bevel pinion is unusual; so are the diagonal distance rods, the spherical seat for the springs, the combination of drawn-steel tubes, steel castings, and pressed-steel cover for the axle housing. The wire wheel and its method of attachment will be seen, also the double set of brakes, internal and external

n the same drum, with operating shafts for both supported from the entral part and ends of the axle housing.

**Rear-Axle Housings.** Rear-axle housings are usually of pressed teel, although castings play a very important part and are someimes used alone and sometimes in combination with other castings or n combination with pressed steel. Aluminum, although not a dependable metal, is used quite a good deal for the purpose of saving weight, as excess weight upon the rear axle is anything but desirable. In one unusual but effective combination, the axle housing consists of two malleable-iron castings joined together by means of bolts at the centers, the brake drums being cast as a part of the tubes. While not usual, this is safe practice, for malleable iron is tough and will not break or splinter. It seldom is the case, however, that the axle casing is reduced to as few parts as are shown here.

*Welding Resorted To.* Where the differential housing or brake drums are of malleable iron, cast steel, or even of pressed steel, and it is desired to unite them with the steel tubing forming the main part of the shaft housing, welding is now universally used. Formerly, it was good practice to make the casing a drive fit on the tube, riveting it in place, or else soldering it in place, making doubly sure by using rivets. Now, however, welding is resorted to, either the oxyacetylene, electric, or some other process being used.

In the axles shown in Figs. 449 and 450, it will be noted that the axle shell is of pressed steel, to which the spring seats are bolted, the remainder of the construction being formed by drawing. In Fig. 448, however, the construction is such as to necessitate making the two halves longitudinally and then bolting or spot-welding them together. Being machined after they are fastened together, it makes as accurate a construction as the one-piece jobs, Figs. 449 and 450.

**Effect of Differentials on Rear Axles.** A differential gear, sometimes called a balance, or compensating, gear, is a mechanism which allows one wheel to travel faster than the other and which at the same time gives a positive drive from the engine. This device is a necessity in order to allow the car to go around a curve properly, for in doing so the outer wheel must travel a greater distance than the inner one during the same interval of time.

There are two forms of differential, the bevel type and the all-spur type, the latter differing from the former only in the use of spur gears

instead of bevel gears. The principle used in both is that a set of gears are so held together that when a resistance comes upon one part of the train of gears the whole train will stop revolving around on a stationary axis and revolve around another gear as an axis, the first gear, in the meantime, standing stationary, or practically so, according to the amount of the resistance encountered. In the bevel type, a pair of bevels are set horizontally. Between the bevels is a spider with three or four arms, with a small bevel on the end of each. These small bevels mesh with the larger bevels at the sides and ordinarily stand still, rotating around on the arm of the spider as an axis by virtue of the continued rotation of the two side gears in opposite directions. When one wheel meets greater obstructions on the road than the other, thus holding it back, the shaft which drives that wheel lags behind the shaft driving the other wheel and thus holds back the horizontal gear attached to the shaft. This retarding movement allows the other horizontal gear more freedom to rotate. The result is that the spider carrying the smaller bevels rotates around on its axis, thus imparting to the free gear attached to the free wheel an additional motion, and to the free wheel a doubled speed, while the retarded wheel has a lessened speed. This takes the car around the corner without breaking the rear axle, as would be the case without some such contrivance. The description of the bevel differential action applies equally well to the spur type, except that all gears are spurs.

Fig. 452. Peculiar Differential Construction

The dividing of the rear axle is, of course, done to make a place for the differential gear to work, and much time and thought have been given to this subject in an endeavor to work out a substitute which

would permit the differential action and still allow the strengthening of the rear axle. Fig. 452 shows one solution of the problem, which has been worked out in such a way that the differential is moved forward into the driving shaft. The rear axle shafts are thus greatly strengthened, the designer being unhampered by the presence of the differential in the rear axle. In this design, one side gear of the bevel-gear differential is carried upon a shaft, and the other upon a tube around the shaft. Then, at the rear axle, two sets of bevel gears $B_2B_3$ and $A_1A_2$ are used, $A_1$ being driven by the main shaft, and driving the right-hand shaft through the gear $A_2$; while the other $B_2$ is driven by the tube, and drives the left-hand shaft through the gear $B_3$. In this case the axle shafts are made much larger than in the ordinary case, while the differential action is just the same.

*Improved Forms of Differential.* Lately, much work has been done upon differentials to cause them to act as differentials should. The present form of differential acts according to the amount of resistance offered, but should act according to the distance traveled. When no resistance is offered, all the power is transmitted to that wheel, leaving the other stationary. This is just the opposite of the desired effect. If a differential were constructed to work for distance only, then, in the case of a wheel on ice or other slippery surface which offered little or no resistance, both wheels would still be driven equally, and the power transmitted to the one not on the ice would pull the vehicle over it.

One way in which the differential action might be corrected is by the use of helical gears and pinions instead of the usual bevel or spur gears. In the M & S forms, this construction is used, Fig. 453, showing the form constructed by Brown-Lipe-Chapin. In this form, each axle shaft carries a helical gear, and the differential spider carries two helical pinions with radial axes and four additional pinions, each of which meshes with one of the radial pinions and one of the gears on the axle shafts. On a turn, the outer wheel tends to run ahead of the inner and thus causes the nest of helical gears to revolve. All gears and pinions have a right-hand 45-degree tooth, so that one wheel may revolve the housing if the other is locked or held, but it is impossible to turn the free road wheel by pulling on the housing. The principle is the same as a worm steering gear in which the turning of the hand wheel may be transmitted to the front wheels, but the gear

cannot be operated from the wheel end, because the worm is irreversible. This differential is used to advantage to prevent spinning on slippery ground and also to eliminate the skidding which the ordinary differential gives.

Another somewhat similar device has but two pairs of helical pinions in addition to the two helical gears on the shafts, the axes of each pair being set at an angle to the others. Thus, each helical gear and its pinion form an irreversible gear combination, so that movement cannot be transmitted through either in the reverse direction. This form fulfills the same conditions as the Brown-Lipe-Chapin M & S form, as the construction is such that no motion can be

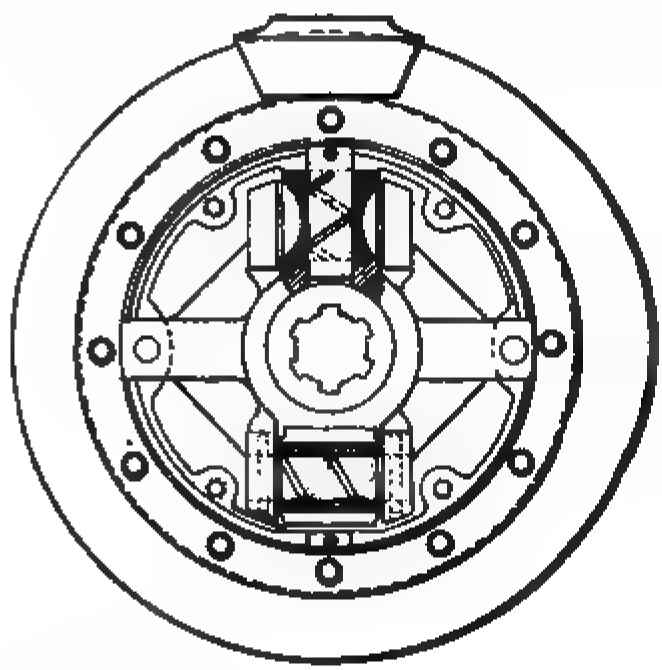


Fig. 453. The M & S Helical Gear Differential in Sections
*Courtesy of Brown-Lipe-Chapin Company, Syracuse, New York*

transmitted from the differential spider or housing to one of the wheels alone.

The above principle is back of the gearless form, shown in Fig. 454, in which the result is achieved through ratchets instead of helical gears, the lack of gears giving it its name. In this form there are two ratchets *Y* and *Y1*, which are keyed to the two axle shafts and free to rotate independent of the housing. The round members marked *B* are the interlocking pawls; the upper one is in a tooth of the right-hand ratchet at the right and is driven by the contact face of the driving sector *X* at the left. Thus, the right-hand ratchet is being driven positively forward. The lower pawl is engaged at the other end; so the left-hand ratchet is also being driven positively

forward. On a turn, one wheel revolves faster than the other, say the right, and causes the right-hand ratchet to move faster than the differential housing, which can only go as fast as the other, or slow-moving, wheel. Then, the right-hand ratchet pushes the end of its pawl out of the tooth and gives it a free movement forward. As soon as the wheels revolve at equal speeds, the spring pushes it back. In the figure, the right-hand portion shows the original form in perspective.

*Possible Elimination of Differential.* The whole modern tendency is toward differential elimination. In the cyclecars and small cars brought out in recent years, designers have been forced to get

Fig. 454. Sketches Showing Construction and Operation of Gearless Differential

along without it because of the demand for simplicity, light weight, and low price. This effect has been obtained by the use of a pair of driving belts, letting one slip more than the other; by the use of friction transmissions; by simply dividing the rear axle and letting one side lag when there was resistance; by not dividing it and letting one wheel drag; and in other ways. The evident success of these small vehicles without a differential or any real substitute for one has set designers to thinking about this subject again, and some big cars without a differential, or with a more simple and less expensive substitute for it, may appear in the near future.

**Rear-Wheel Bearings.** The bearings used on rear axles differ very little from those used on front axles. All forms are used—plain

bearings, ball bearings, ball thrusts, roller bearings in both cylindrical and tapered types, and all combinations of these. Thus, Figs. 445 and 452 show the exclusive and liberal use of ball bearings, while Fig. 451 shows all rollers of two kinds and ball bearings for thrust bearings only. The two kinds of roller bearings are the tapered roller and the flexible roller. Similarly, in Fig. 447, it will be noted that balls are used with two kinds of rollers, straight solid rollers in the wheels and flexible rollers in the differential case. Figs. 449 and 450 show the exclusive use of the tapered roller type, a construction which is gaining ground very rapidly, the same as in front axles, although, formerly, ball bearings were most widely used. The materials employed are similar to those used for front axles, which have been previously described. Cases are made of all kinds of steel and iron—pressed, drawn, cast, etc.—not to speak of crucible steel, malleable iron, manganese bronze, phosphor bronze, aluminum, aluminum alloys, and many combinations of these materials in twos and threes.

**Rear-Axle Lubrication.** Rear-axle lubrication is generally automatic in so far as the central bevel or other gears and the differential housing are concerned. The housing usually has a form of filling plug, or standpipe, which is used to fill the case with a form of heavy grease every 5000 miles, or once each season. The case is generally arranged so the filling plug works through and lubricates the outer bearings on the axle shafts as well, with suitable provision against this reaching the brake drums or other brake parts. The wheel bearings either are cared for in this way or have a central space which is filled with heavy grease once a season, being self-lubricating from then on. Such other rear axle parts as need occasional lubrication, as torque-rod pivots, brake-band supports, brake-operating shafts, etc., are generally provided with external grease cups, which are given a turn once a week on the average. It is highly important that the braking system be as well lubricated as the lubricating means provided will allow.

## REAR-AXLE TROUBLES AND REPAIRS

**Jacking-Up Troubles.** Much rear-axle work—practically all, in fact—calls for the use of the jack. True, the full floating type of axle can have its shaft removed without jacking, but, aside from differential removal, there is little rear-axle trouble in which it is

necessary to remove the shaft alone. In almost all cases, the axle must be jacked up. Many axles have a truss rod under the center, and this is in the way when jacking; however, this can be overcome. Make from heavy bar iron a U-shaped piece like that shown on top of the jack in Fig. 455, making the width of the slot just enough to admit the truss rod. The height, too, should be as little as will give contact with the under side of the axle housing.

*Substitute for Jack.* A good substitute for a jack is a form of hoist, Fig. 456, which will pick up the whole rear end of the car at once. This not only saves time and work, but holds the car level, while jacking one wheel does not. Moreover, with a rig of this kind, the car can be easily lifted so high that work underneath it may be easily done. The usual hoisting blocks are very expensive, but the above hoist can be easily made by the ingenious repair man. This one was made from an old whiffletree with a chain attached at each end. For the lower ends of the chains, a pair of hooks are made sufficiently large to hook under and around the biggest frame to be handled. With the center of the whiffletree fastened to the hook of a block and tackle, the hoist is complete. By slinging the hooks under the side members of the frame at the rear, it is an easy matter to quickly lift that end of the chassis any distance desired.

**Workstand Equipment.** Next to raising the rear axle, the most important thing is to support it in its elevated position. To leave it on jacks is not satisfactory, for they will not raise the frame high enough, and, furthermore, they are shaky and may easily let the whole rear end fall over, doing considerable damage. With the overhead hoist, the chains or ropes are in the way; so a stand is both a necessity and a convenience. In Fig. 457, several types of stands are shown. *A* is essentially a workstand, intended to hold the axle and part of the propeller shaft while repair work is being done thereon. It consists of a floor unit, or base, built in the form of an *A*, with six uprights let into it, preferably mortised and tenoned for greater strength and stiffness. Then, the four rear uprights are joined together for additional stiffness and rigidity. If casters are added on the ends, the stand can be more conveniently handled around the shop.

The forms *B* are for more temporary work and consequently need not be so well or so elaborately made. The little stand *C* is a very handy type for all-around work. Stands of this kind with the

top surface grooved for the axle are excellent to place under cars which have been put in storage for the winter.

The stand *D* is, like *A*, a workstand pure and simple. In this, however, the dropped-end members allow supporting the axle at

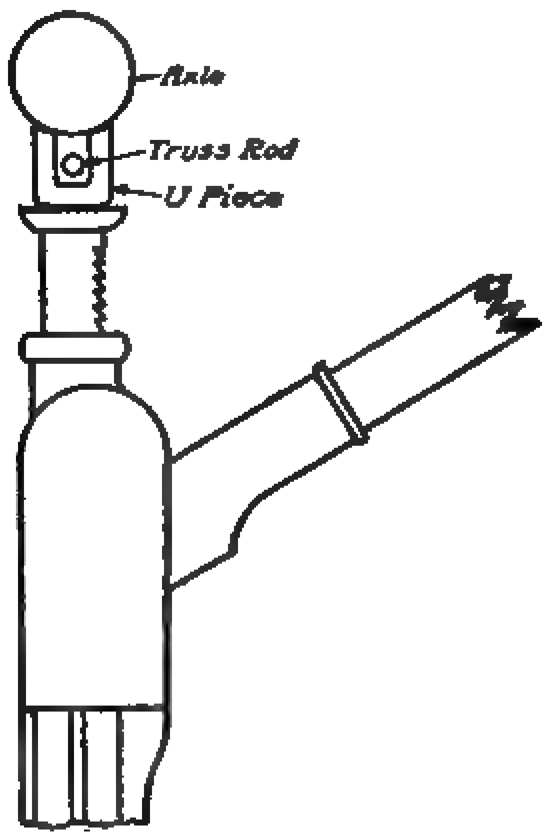



Fig. 455. Simple Arrangement for Avoiding Rear-Axle Truss Rod

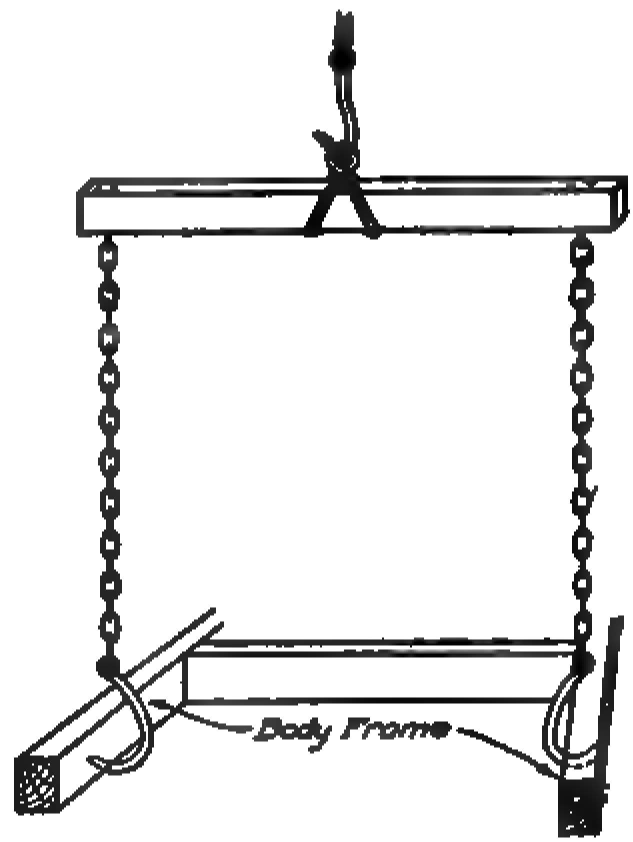



Fig. 456. Simple Automobile Frame Hoist

those points, while the elimination of central supports gives plenty of room for truss rods. This type of stand would preferably be made from metal, pressed steel or small angle irons being very good. Every

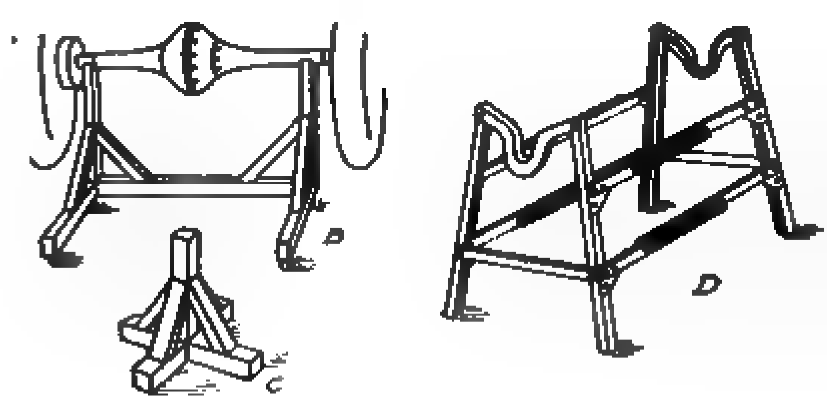



Fig. 457. Types of Handy Stands for Rear-Axle Repair Work

repair shop should have a considerable number and variety of stands, made as the work demands them, to fit this particular class of work.

**Universal-Joint Housings.** Universal joints usually are covered with leather casings which are packed with grease. These keep out

the dirt and, consequently, lessen the wear, and also lubricate the moving parts of the joints. A secondary function of the casings is to render these joints noiseless. If a car is not equipped with them, it is advisable for the owner to purchase them.

The shape of these casings, when opened out flat, would be not unlike that of two bottles with their flat bottoms set together, that is, narrow at the top and bottom and wider at the middle. All along both edges are eyelets for the lacing. The enlarged center fits around the joint, while the small ends encircle the respective shafts. To apply the casing, one end is placed around the shaft on one side of the joint, and the lace started; then the lacing proceeds, gradually drawing the ends together and around the joint. When this has been completed, and before the last end is closed, the whole is shoved back along the first shaft a little way, and the center portion half filled with a heavy grade of transmission grease. This done, the glove is pulled back into place, and the work of lacing completed around the second shaft. Both ends should be laced as tightly as possible, while the middle part should be loose. Sometimes these housings will become worn and make a very annoying chatter on the road, even when they are not sufficiently worn to warrant replacements. Under such circumstances, the offending member may be wound with tire tape held firmly in place in addition to its adhesive power by means of a hose clamp, as shown in Fig. 458. The coupling is held tightly enough to prevent the rattle and chatter, but not enough to interfere with its action. While not a handsome job, it does the business, stopping the noise effectively.

**Rear Axle.** Rear axles do such hard work and must stand up under such a large portion of the load carried in the machine that they offer many chances for wear, adjustment, or replacement.

*Truss Rods.* Truss rods hold the wheels in their correct vertical relation to the road surface and to one another. If, through wear or excessive loading, the axle sags so that the wheels tip in at the top, presenting a knock-kneed appearance, the truss rods must be tightened up. Usually, they are made with a turnbuckle set near one end, a locknut on each side preventing movement. The turnbuckle is threaded internally with a right-hand thread on one end and a left-hand thread on the other, so that a movement of the turnbuckle draws the two ends in toward one another, shortens the length of the rod,

and thus pulls the lower parts of the wheels toward one another, correcting the tipping at the top.

To adjust a sagging axle, loosen both locknuts, remembering that one is right-handed and the other left. Then, with the wheels jacked clear of the ground, tighten the turnbuckle. A long square should be procured or made so that the wheel inclinations may be measured before and after. Placing the square on the ground or floor, which should be selected so as to be perfectly level, the turnbuckle should be moved until the tops appear to lean outward about ½ inch—some makers advise more.

It should be borne in mind that even if the wheels and axle do not show the need of truss rod adjustment, if this rod be loose, it will become very noisy and rattle a great deal, as the rear axle sustains a great amount of jouncing. Moreover, this noise and rattle, if not taken up, will cause wear, which cannot be taken up.

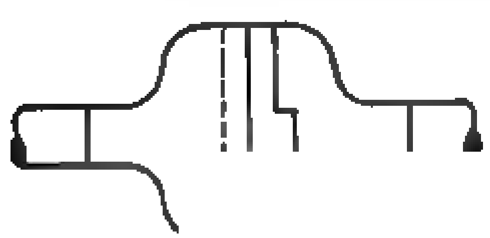


Fig. 458. Easy Method of Quieting Noisy Universal-Joint Housings
*Courtesy of "Motor World"*

*Disassembling Rear Construction.* In disassembling the rear construction for purposes of adjustment or repair, the repair man should be careful to mark all parts. Those parts which have been running together for several thousand miles act better and with less friction than would those which have never run together, despite the fact that the duplicate parts are supposed to be alike and interchangeable. It is therefore suggested that separate boxes be provided for the parts taken from the two ends or sides. The method of disassembling is about as follows: Jack up the axle, replacing the jack with small horses or blocks of wood if possible. Take off the hub caps, then free the wheels and take them off. Disconnect the brake-operating rods and levers and remove them from the car, marking them carefully. Spread the brake shoes apart, loosen the springs at one side, take out the springs, and then loosen and take out the brake shoes themselves. Remove the brake operating shaft with the cams;

then disconnect the spring bolts and jack up the chassis, using the spring for a support. Disconnect all torsion or radius rods and take off the grease boot around the universal joint in the driving shaft. Open this joint and disconnect the shaft. Take this off, and if the spring bolts have been removed, the rear axle will be free. Pull it out from under the chassis, and, if desired, further disassembling may be done more easily with the member clamped in a vice or laid on a bench.

*Assembling.* In assembling, almost the reverse of this process is followed, the parts going together in the opposite manner from that in which they were taken down.

**Noisy Bevel Gears.** If the bevel gears in the rear axle are noisy, the time to fix them is when the axle is disassembled, as this is quite a job. In general, bevel gears make a noise because they are poorly cut, because they are not set correctly with relation to each other, or because the teeth have become cut, or chipped, by some foreign material which has been forced between them.

In the first case, there is little the amateur can do beyond making the best possible adjustment and smoothing off any visible roughness. In the second case, it is simply a matter of setting one gear closer to or farther from the other by means of the adjustment provided. When the axle is disassembled, and all parts are readily accessible, it will be found that there is a notched nut on either side of each of the bevels; there should be a wrench in the tool kit to fit this. It is then a simple matter to move one outward and the other inward in either pair, according to which needs the adjustment. In case the teeth have become chipped, the projections should be smoothed down with a fine file, while the sharp edges of the cuts should be dressed in the same manner.

*Packard Bevel Adjustment.* Although strictly a transmission trouble, the older Packard cars have the transmission located on the rear axle, and this position made the adjustment of the bevel pinion difficult. For another thing, the shaft is very short and hard to hold. If the sliding gear on the shaft is meshed with the internal gear attached to the other end of the bevel-pinion unit, the latter will hold firmly, but there will still be a little play between the teeth. It is necessary to take this up, as otherwise the repair man would mistake this play for play in the bevel driving gear. It can be taken up as

follows: Take an old sliding-gear unit from one of these transmissions, remove one of the teeth and slide the gear into position for meshing with the space at the top between two teeth on the good gear. Drive a pin in where the tooth has been removed, and this will fix the two firmly together without a particle of play. Then, by removing the cover from the differential housing, the bevels can be tested for play. Fig. 459 shows the transmission, bevel gears, and axle parts, also the gear with the tooth removed and replaced by a pin, so that the whole process will be clear.

*Repair for Broken Spring Clips.* The springs are held down on the axles by means of spring clips, which are simply U-shaped bolts

Fig. 459. Diagram of Packard Axle and Transmission to Show Adjustment of Bevel Pinion
*Courtesy of "Motor World"*

with the inside width of the U equal to the width of the spring. Occasionally, these will break when they cannot be replaced or new ones forged. Under such circumstances, a repair such as used by one man, shown in Fig. 460, will always get the car home or to a garage where a better one can be made. This method of repair consists of a pair of flat plates, one above the spring, the other below the axle, with holes drilled in the corners to take four long carriage bolts, which happened to be handy. The plates were put on, bolts put in and tightened up, and the car was ready to run. Although an I-section axle is shown, this method of repair would work just as well on a round axle or on one of any other shape.

*Lining Up Axles.* In such a repair, however, the main thing is to get the rear axle lined up correctly, which is not an easy job. This may be done in the following manner: Get the car standing level on a nice clean smooth floor; hold a large metal square with a plumb bob hanging down over its short edge against the side of the frame. Move the square forward until the line just touches the rear axle at some set distance out from the frame, say 3 inches, as shown in Fig. 461. Then notice the distance this line is forward from the rear end of the frame. In the sketch it is 16 inches. Transfer the square and plumb bob to the other side and repeat. Here it will be found that the distance from the rear end of the frame is either more or less. In the sketch it is shown at 18 inches; so the difference, 2 inches, shows that the axle is out of alignment that much or half that, 1 inch at each end.

This axle is straightened by loosening the spring bolts and pushing one side back the distance apparently needed, then fastening tightly and checking up. If not correct, try again, using judgment as to which side should be moved. When finally satisfied that the rear axle is square with the frame, it is well to check this against the center-to-center distance of the wheels on each side. This is done by setting the front wheels exactly straight and then measuring from the center of the right front to the center of the right rear wheel. Then go over to the other side and measure the center-to-center distance of the left wheels. The two axles should agree exactly. If they do not, the rear axle prusumably needs more adjustment for squareness.

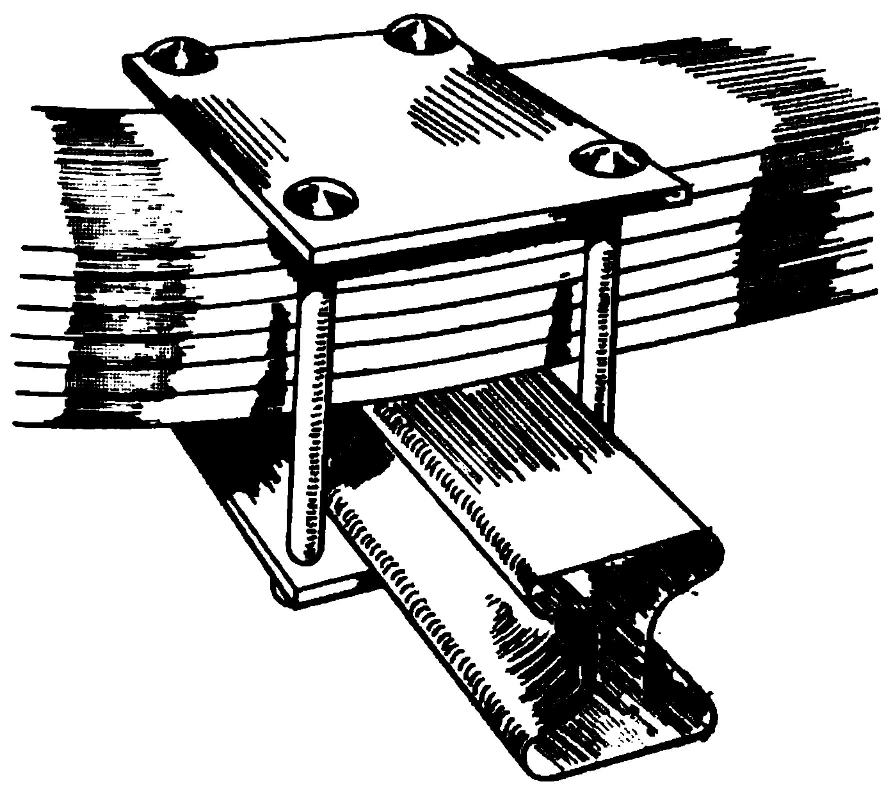


Fig. 460. How Spring Clips Are Replaced in Emergency
*Courtesy of "Motor World"*

*Taking Out Bend in Axle.* A simple method of repairing an axle which has been bent, but a method which is only temporary in that it is not accurate enough to give a job which could be called final, is that indicated in Fig. 462. The axle was bent when the hub struck an obstruction in the road, and it had to be straightened immediately.

A short length of 2 x 4 timber was cut to be a tight fit between the upper side of the hub cap and the roof beam. Then a jack under the

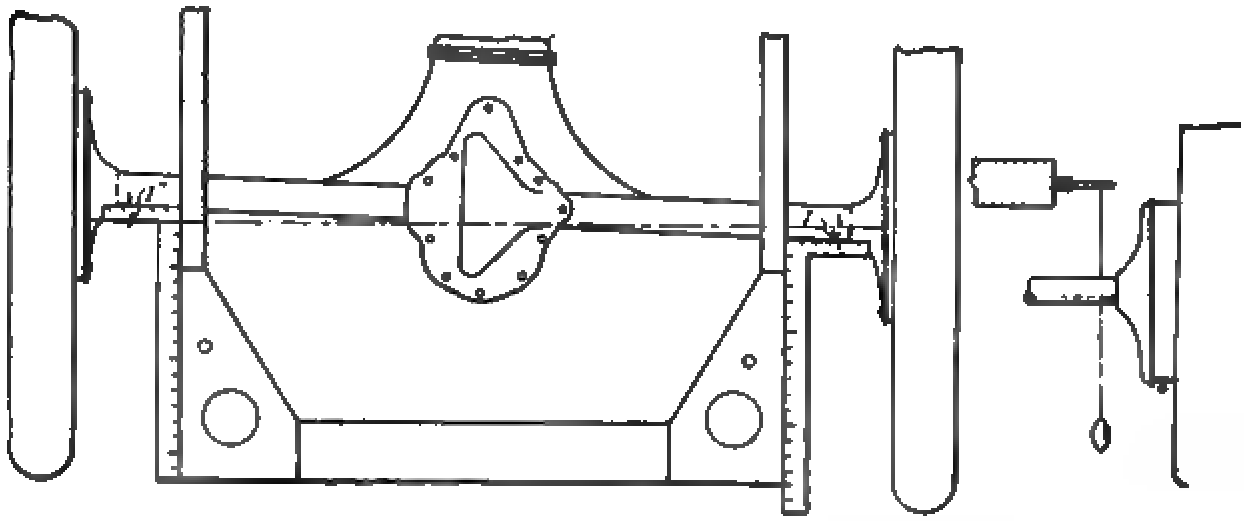


Fig. 461. Method of Checking up Rear-Axle Alignment with Square and Plumb Bob

axle at the point of the bend was raised. As the jack raised the axle, and the wood beam held the hub down, enough pressure was exerted to force the axle to give at the bend and return as nearly as possible to its original straightness. It was a quick and easy repair of the rough and ready order, which served when time was worth more than anything else; but it is a method which would not be advised or recommended when there was sufficient time to properly straighten the axle.


Fig. 462. One Way of Straightening Rear Axle Quickly

**Locating Trouble.** Many times, a car may be brought in for rear-axle repair on which the repair man cannot find any trouble. Many axles often develop an elusive hum, or grinding noise, which not only defies location, but is not continuous. The writer had such a case brought to him at one

time, and was sure that the bevel gears were out of alignment and were cutting each other. It was a low-pitched whine which was not apparent at low speeds, but began to be heard around 18 to 20 miles an hour, and at times was very apparent. The noise was very annoying, but tearing down the rear construction showed absolutely no trouble; so the noise could not be at that point. Sometime later the noise was definitely located in a pair of worn speedometer gears on the right end of the front axle.

A good way to listen to rear axle hums out on the road is to lay back over the rear end of the car, Fig. 463, with the head against the top of the seat and projecting over slightly, and with the hands cupped in front of the ears, so as to catch every noise that arises. The larger sketch shows the general scheme, the small inset giving the method of holding the hands. When the sound arising from the axle is a steady hum, the gears are in good condition and well adjusted. If this sound is interrupted occasionally by a sharper, harsher note, it may be assumed that there is a point in one of the gears or on one of the shafts where things are not as they should be. By trying the car at starting, slowing down, running at various speeds, and coasting, this noise can be tied to something more definite, some fixed method of happening. In advance of actual repair work, including tearing down the whole axle, the gears can be adjusted. This can generally be done from outside the axle casing and without a great deal of work. If the adjustment makes matters worse, it can be reversed, or if it improves the situation, the adjusting can be continued, a little at a time, until the noise gradually disappears.

Fig. 463. Listening for Rear-Axle Noises

**Checking Up Ford Axles.** Many cases of Ford bent rear axles can be fixed without taking down the whole construction. The principal point is to find out how much and which way the axle is bent.

By removing the wheel on the bent side and placing the rig shown in Fig. 464 on the axle end, the extent of the trouble can be indicated by the axle itself. The iron rod is long and stiff, with its outer end pointed, and is fastened permanently to an old Ford hub. The rig is placed on the axle and held by the axle nut, but without the key, as the axle must be free to turn inside the hub. With the pointed end of the rod resting on the floor and with high gear engaged, have some one turn the engine over slowly, so as to turn the axle shaft around. As it revolves, the hub will be moved, and the pointed end on the floor will indicate the extent of the bend. By marking the two extreme points and dividing the distance between them, the center is found. Then a rod can be used as a bar to bend the axle, until the pointed rod end is exactly on the center mark. A little practice with this rig will enable a workman to straighten out a Ford rear axle in about the time it takes to tell it.

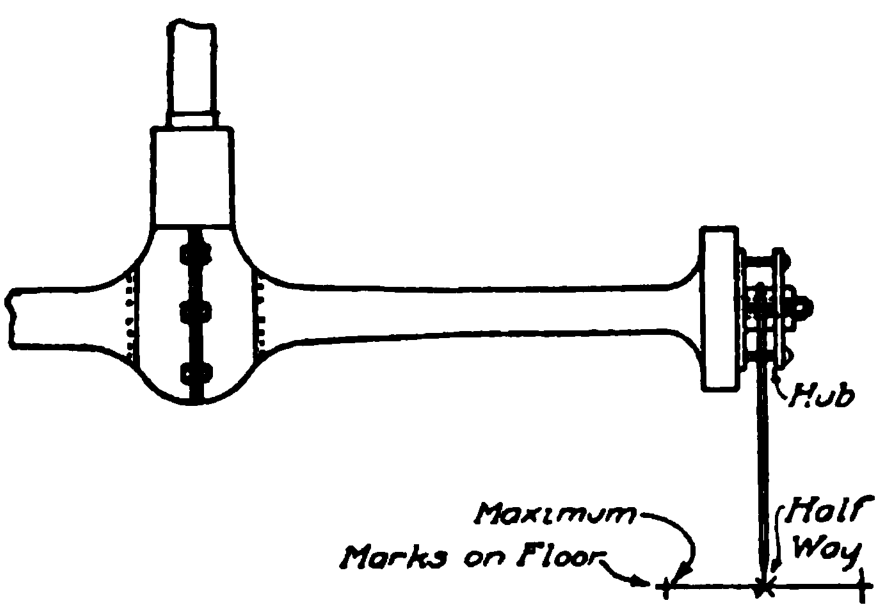


Fig. 464. Diagram Showing Method of Checking Up Ford Axles

## BRAKES

**Function of Brake.** Next to power, applied through the correct form of gearing, and its final suitable drive to the road wheels, nothing is of more importance than the ability to stop the vehicle at will. One medium through which this is done, and which ordinarily suffices, is the shutting off of the source of power—in this case, the gasoline and the spark which is used to ignite its vapor. This will not always suffice, however, for the ordinary car possesses the ability to run at a speed of 40 miles per hour or upward, and weighs from 2000 pounds (one ton) upward to 4000 pounds (two tons). This combination makes for a large force of inertia, which will result in the car running for many yards, even hundreds of yards, after the power is shut off. It is for this reason that we must have a mechanical means of absorbing this inertia, or of snubbing the forward movement of the car. This is the function of the brakes, as fitted to the modern car.

*Engine as a Brake.* Although disregarded in any summary of brakes, the engine is the best brake possible, granting that the driver knows how to get the best results without doing any damage. The ordinary engine has a compression of from 60 pounds to 70 pounds per square inch, which is practically the pressure available when it is used as a brake. Since this is more pressure than any other type, or form, of brake will yield, its usefulness is self-evident.

**Classification.** Brakes are usually divided into two classes, differing mainly in location—the internal expanding and the external contracting. To these a third class should be added, because it partakes of the nature of both, yet differs from each one. This is the railway type of brake with removable shoes of metal, differing from the band type in that no attempt is made to cover the whole or even the greater part of the circular surface, but simply a small portion of it, against which a shoe is forced with a very high pressure. Both the other types are subject to division into other classes, the first into three subdivisions according to operating means, viz, cam, toggle, and scissors action.

Brakes are generally divided according to their location, as shaft and rear axle. The shaft brake at one time virtually went out of use, but it is now being revived. The marked swing toward the unit power plant, together with its simplification, lightening, and elimination tendencies, has produced a situation where a brake drum just back of the power and gear unit can be operated by the hand lever and a very short rod. In this way much weight and many parts are saved. An indirect advantage is that the brake is more accessible. With the worm drive, there is a marked tendency back to the shaft brake, particularly on motor trucks. Again, in the last few years, some work has been done with pneumatic, hydraulic, and electric forms of brake. With air under pressure for starting, and with water or electricity as needed for starting or for other purposes, it is a simple matter to utilize the same agency for braking, providing such use does not add too much complication and, at the same time, that it will give a superior method of snubbing the forward movement of the car. In case none of these advantages are realized, there will be no particular advantage in adding new forms of brake.

**External-Contracting Brakes.** This class of brakes is divided nto but two types, viz, single- and double-acting. In the first, an

end of a simple band is anchored at some external point, while the other, or free end, is pulled. This results in the anchorage sustaining as much pull as is given to the operating end, that is, all pull is transmitted directly to the anchorage. This disadvantage has resulted in this form becoming nearly obsolete.

Any brake of the true double-acting type will work equally well acting forward or backward. The differential brake, Fig. 465, shows this clearly. The external band is hung from the main frame by means of a stout link which is free to turn. The band itself is of very thin sheet steel, lined with some form of non-burnable belting. The ends carry drop forgings, to which the operating levers are attached. These are so shaped that the pull is evenly divided between the two sides of the band. This will be made apparent by considering that a pull on the lever *H* will result in two motions, neither one complete, since each depends upon the other. First, there will be a motion of the upper band end *B* about the extremity of the lower one as a pivot, followed by a movement of the lower end, pivot and all, about *B* as a second pivot point. These two motions result in a double clamping action which is supposed to distribute evenly over the surface. In order to insure even distribution, the lining is grooved, or divided, into sections.

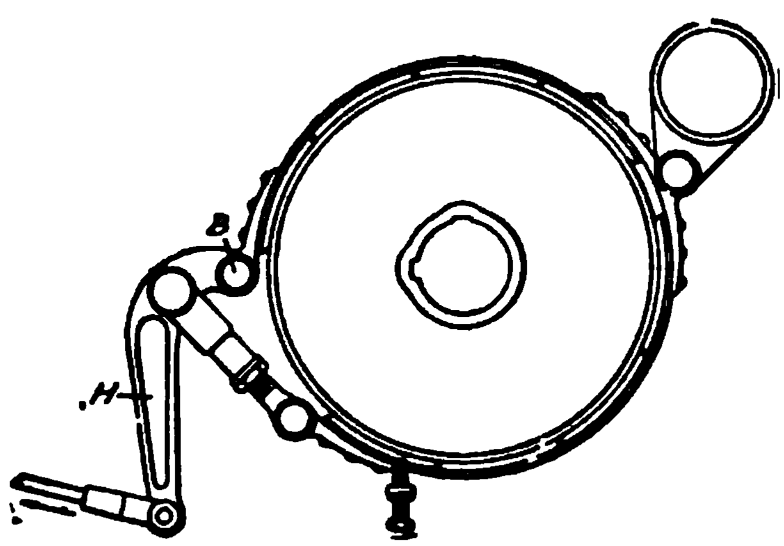



Fig. 465. Brake on Main Shaft of Benz (German) Car

Usually, chain-driven cars have a different brake location from a car with shaft drive. The chain-driven cars have three sets of brakes: one on the main shaft, one pair on the countershaft, and another pair on the rear wheels, as shown in Fig. 466.

**Internal-Expanding Brakes.** While the contracting-band brake is well thought of, the internal-expanding form is rapidly displacing it, for the reason that experienced drivers think more of it. In Fig. 467 will be seen a modern form of the internal brake, namely, the use of both brakes as internal, but placed side by side in the same drum. This is a tendency which seems to be gaining in favor. The car is the Owen Magnetic, one of the most expensive and luxurious; so the use

of side-by-side internal brakes here must be attributed to superiority rather than to a desire to save in money or in parts.

A considerable number of foreign cars, which are used in mountainous countries, show a method of cooling the brake drums by means of external cooling flanges. In some makes, even a water drip is provided for extremely hilly country.

More modern practice shows no tendency to place all of the eggs in one basket, both forms of brake being employed together and upon the same car, usually also upon the same brake drum, one set working

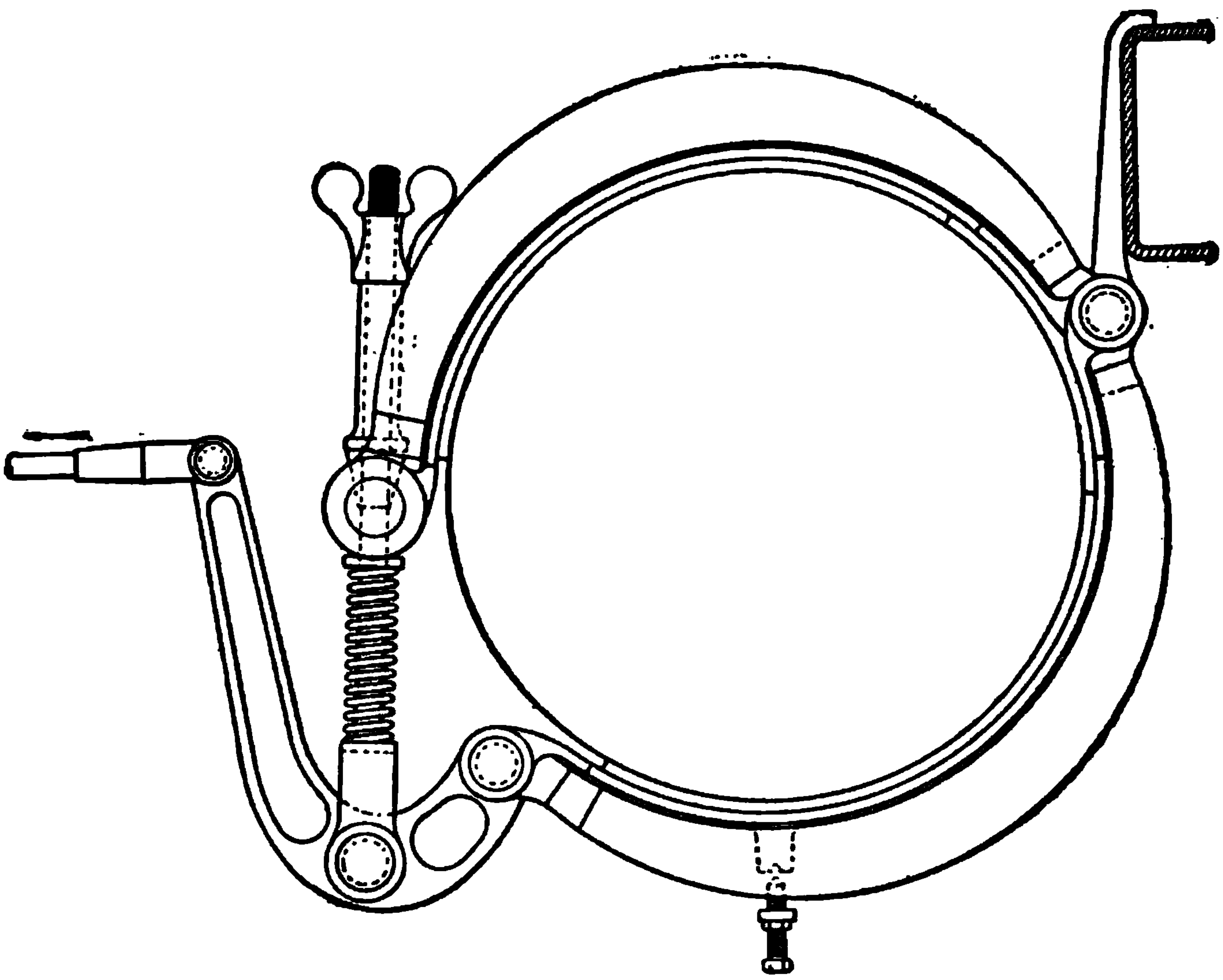


Fig. 466. Benz Countershaft Brakes for Chain-Driven Car

upon the exterior, while the other works upon the inside. In Fig. 468, which shows the rear-axle brakes of the larger cars made by the Peerless Motor Car Company, this mechanism is plainly illustrated, both the brakes being shown, although the drum upon which they work has been removed. The parts are all named so as to be self-explanatory. In this construction, the inner, or expanding, band is operated by a cam. In the brake sets put out by the Timken Roller Bearing Company, of Detroit, Michigan, in connection with their bearings and axles, the toggle action is used, Fig. 469. The constructional drawings, Figs. 470 and 471, showing the brakes used on the Reo car, manufactured by the Reo Motor Car Company, of Lansing,

Michigan, indicate that this firm is partial to the cam for brake operation, since these are used for both internal and external brakes, the

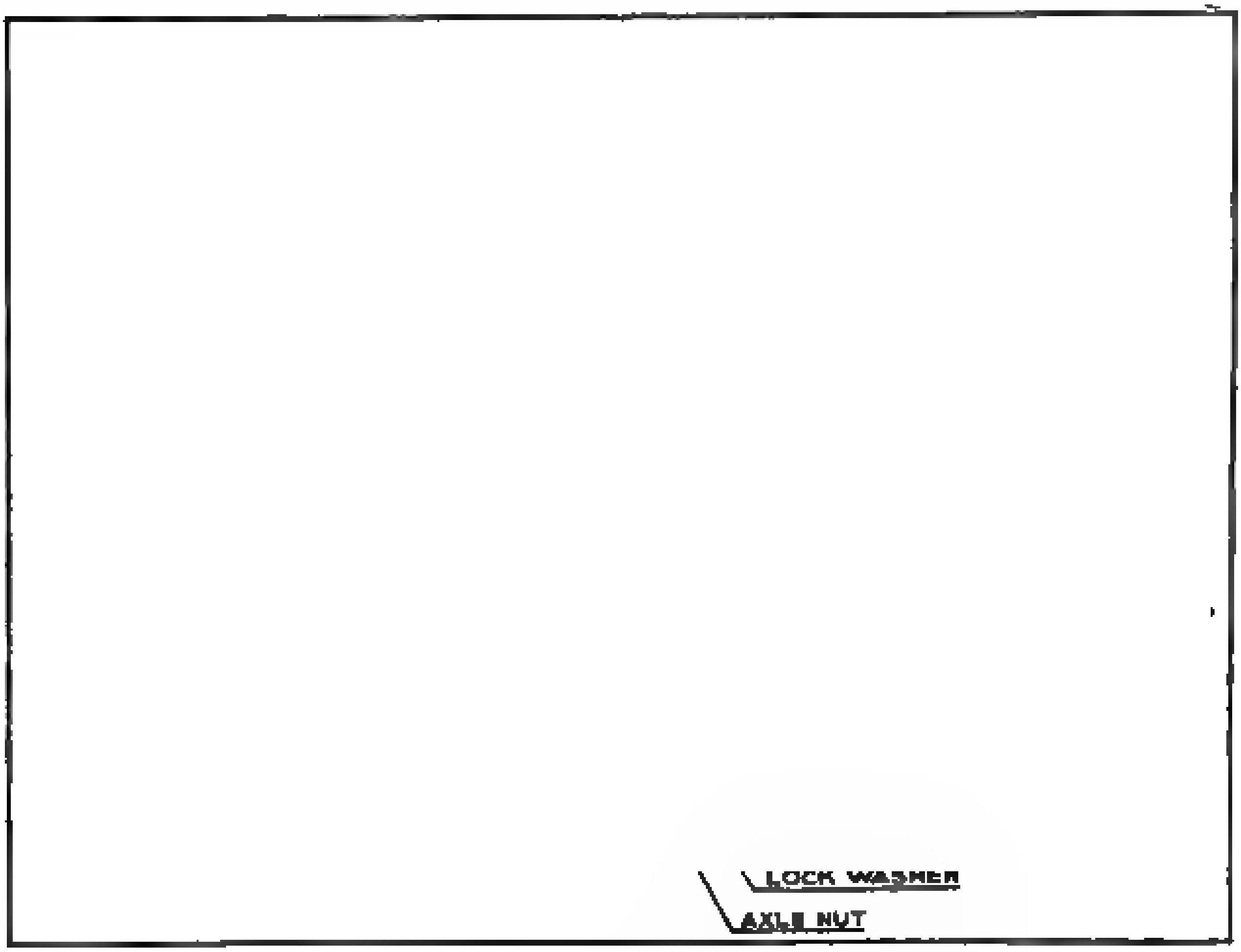



Fig. 467. Rear Axle of Owen Magnetic Car with Wheel Removed to Show Brakes
*Courtesy of Baker-R & L Company, Cleveland, Ohio*

Fig. 466. Peerless Rear-Axle Brake

internal form having a split link connected to the toggle, while the external has a link movement in contracting much like that shown in Fig. 465, which is there explained in detail.

In general, however, when both brakes are placed on the rear wheels, one external and of the contracting-band type, and the other internal and of the expanding-shoe form, modern practice calls for a cam to operate the latter, operating directly upon the ends of the two halves of the shoe, while levers operate the band so as to get a double contracting motion.

Some modern brakes may be seen in Figs. 472, 473, and 474. The first shows a system such as just described; the second shows a stiff metal shoe in both types; and the last a pair of shoes set side by side. In addition, the last-named includes a new thought in

Fig. 469. Timken Double Rear-Axle Brake

Fig. 470. Section Showing Construction of Reo Brakes

Fig. 471. Drawing Showing Method of Operating Reo Brakes

*Courtesy of Reo Motor Car Company, Lansing, Michigan*

that the brake shoes are floated on their supporting pins, as shown. This makes the bearing of the shoes certain when expanded against every portion of the drum, as the shoes can "float" until they fit exactly.

**Double Brake Drum for Safety.** A very important feature is pointed out in Fig. 472, namely, that of safety. Where both brakes work on a common drum, one inside and the other outside, the continuous use of the service brake (whether internal or external) heats up the drum to such an extent that when an emergency arises calling for the application of the other brake it will not grip on the hot drum, being thoroughly heated itself. The double drum allows air circulation and constant cooling.

**Methods of Brake Operation.** While it is generally thought that round iron rods are the universal means of brake operation, such is not the case. Many brakes on excellent cars are worked, as the illustrations show, by means of cables. This idea is even carried so far

Fig. 472. Double Brake Drum Used on Locomobile Cars

that brakes have been fitted to operate through the medium of ropes. Chains of small diameter have also been used, as well as combinations of rods, chains, cables, and ropes.

A lever-operated braking system of a well-known medium-priced car is shown in the outline sketch, Fig. 475. In this system the forward part of each half is worked by rods moved by means of pedals, but the rear part of each half is actuated by means of cables. Cables have one advantage over rods in a situation like this—the diagonal pull with a stiff rod might, in time, act to pull the brakes side-

Fig. 473. Brakes and Rear Construction of Pierce Cars
*Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York*

Fig. 474. Side-by-Side Arrangement of Brakes on American Rear Axle
*Courtesy of American Ball Bearing Company, Cleveland, Ohio*

wise off their respective brake drums, the cable, being more flexible, gives less danger of this.

This method of operation seems to be gaining favor because of its simplicity, which eliminates parts that add weight and gives immediate results when the parts are properly adjusted. The recent New York show revealed a surprising number of small and medium size cars with cable-operated brakes. An inspection of these cars showed a mechanical cleanliness which was lacking in many others of the same class on which an attempt was made to reduce braking rods

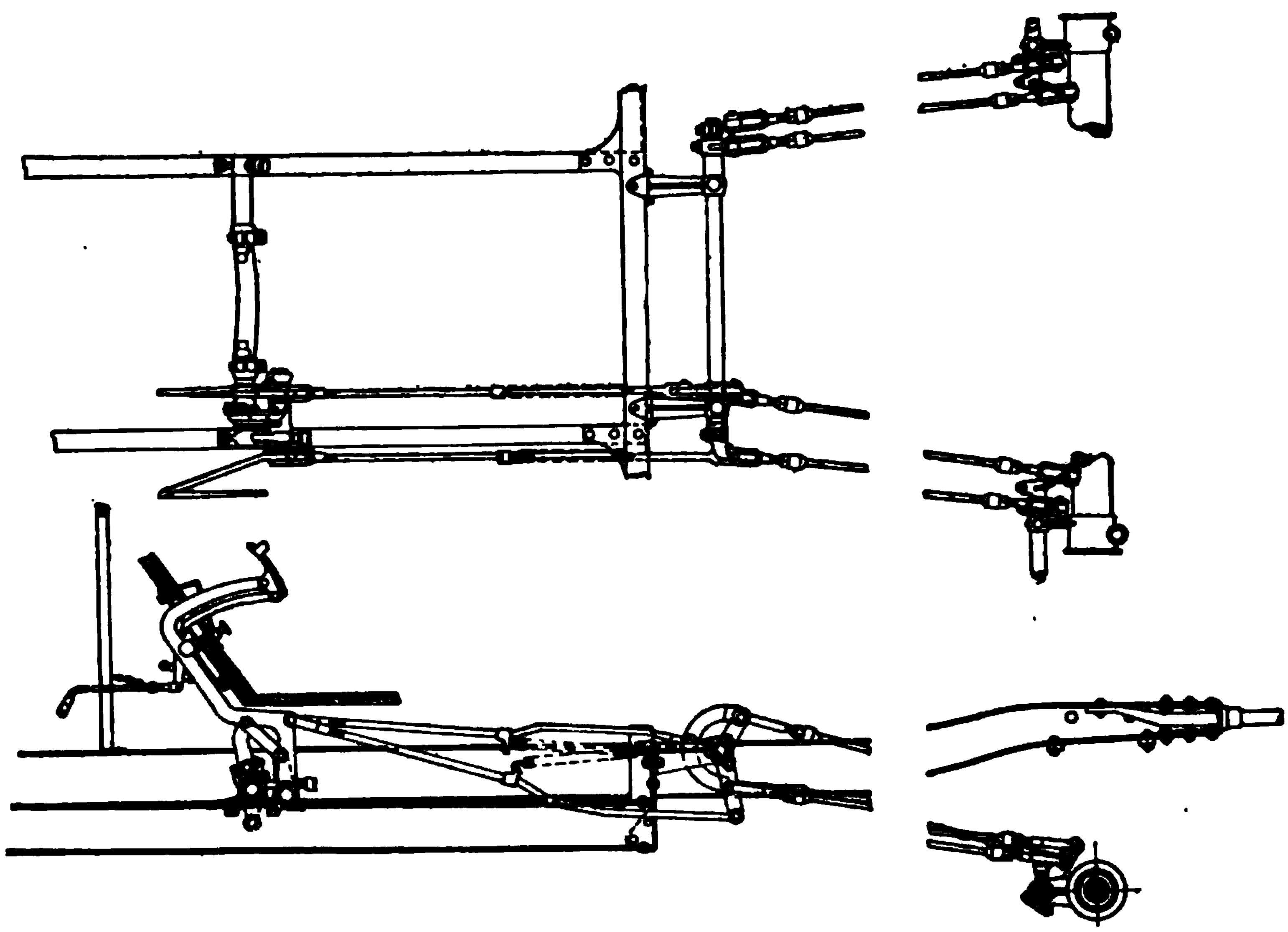


**Fig. 475. Layout of Brake-Operating System Using Cables**

and levers to a minimum, with consequent bent levers, bent or crooked rods, brakes worked from an angle, and other unmechanical ideas.

Fully as important as the operating means is the matter of equalizing the pull so that the same force is exerted upon both wheels at once. This action is influential in causing side-slip or skidding, which may result fatally. To equalize the force was one reason for the use of cables, although the more up-to-date way is to attach the operating lever to the center of a long bar, to the extremities of which the brakes themselves are fastened. A pull on the bar is then divided into two different pulls on the brakes, the division being made automatically and according to their respective needs. This is an

important point, and one that should be looked after in the purchase of a new car.

**Brake Adjustments.** In recent years much of the brake improvement has been that of making adjustments easier and of making the adjusting parts more accessible. This can be noted in such a case as the Locomobile, Fig. 472, where the special adjusting handle on the brake is carried to such a height as to make the turning of it an easy matter. Similarly, on the Pierce, Fig. 473, it will be noted that there is provision for increasing or decreasing the closeness of the shoes to the drum, which is easily accessible.

**Brake Lubrication.** As for the actual brake surfaces, there is no such thing as lubrication. The surfaces should be kept as dry and clean as possible. If grease or oil gets out from the axle or other lubricated parts onto them, there is sure to be trouble. The operating rods and levers, however, should have fairly careful lubrication, for which purpose the best makers provide grease or oil cups at all vital points. If these be neglected, a connection may stick, so that when an emergency arises the brake will not act properly and an accident may result.

**Recent Developments.** In the last few years, the only new ideas advanced in the way of brakes concern front-wheel braking and electric brakes. The former were used quite extensively abroad in 1913, but in 1914 they seemed to drop back; this, too, despite the fact that the Grand Prix race of the latter year showed in a marked manner the need for and special application of front-wheel brakes to racing and high-speed cars.

**Electric Brakes.** A very efficient and compact brake, applicable with a small amount of work to any chassis having a storage battery, is the Hartford, shown in Fig. 476, while Fig. 477 shows the operating lever as it is placed beneath the steering wheel, and Fig. 478 shows the wiring system. This brake consists, in substance, of a small reversible electric motor, to which a 100 to 1 worm reduction is attached. Attached to the drum is a cable, which is fastened to the usual brake equalizer. Turning the current into the motor from the storage battery rotates the drum, winds up the cable, and applies the brake. The complete outfit weighs but 35 pounds. The motor has a slipping clutch set to operate at 1000 pounds pull, at which it draws 40 amperes of current from the battery for two-fifths of a second.

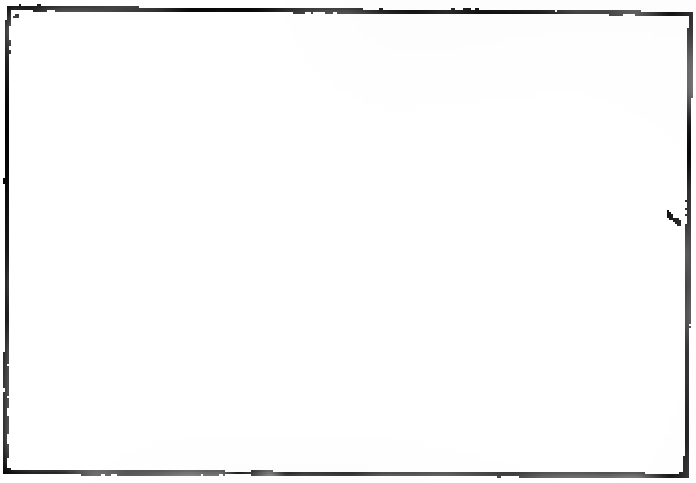


Fig. 476. Exterior of Motor Which Forms Central Unit of Hartford Electric Brake
*Courtesy of Hartford Suspension Company, Jersey City, New Jersey*

Fig. 477. Hand Lever on Steering Post for Operating Hartford Electric Brake

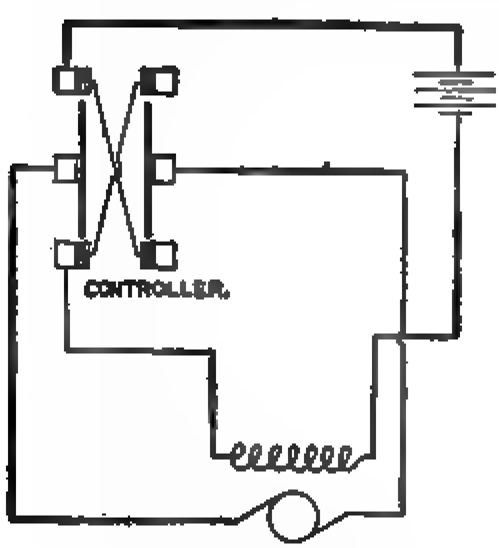



Fig. 478. Wiring Diagram for Hartford Electric Brake

In use, it replaces the emergency hand-operating lever, and is said to be able to pull a heavy car going 50 miles an hour down to less than 15 in a distance of less than 35 feet. The pull is so great that the brake drums are oiled to prevent heating and possible seizing.

**Hydraulic Brakes.** On the newer Knox tractors, a brake of very large size is made even more powerful by hydraulic operation. This brake is shown in Fig. 479. At the left will be seen the usual brake lever attached to a small piston in a chamber full of liquid. This chamber communicates through the medium of a valve normally held closed by a spring, with a passage above, and that, in turn, communicates with the pipes leading to the brake-operating cylinder. This cylinder has a stout rod attached to a good size plunger, back of which the liquid (oil) is introduced. When liquid is forced in, the plunger moves forward, forcing the rod out and, through connecting rods and levers, applying the brakes. As will be seen in the drawing at the right, these brakes, which are of the

internal-expanding type, are exceptional in size and work against steel drums attached directly to the wheel spokes.

When the lever is drawn back in the usual manner, liquid is forced upward through the top passage to and through the pipes into the other cylinder, forcing the plunger to move, and, through the movement of the plunger, the brakes are applied. The return of the fluid is not shown, but it is assumed that this is through a simple pipe connection from the plunger cylinder to the hand-operated piston with a check valve. Should the initial movement of the lever fail to apply the brakes sufficiently, the driver can let the lever come forward and then pull it back again; in so doing he will take into his lever cylinder

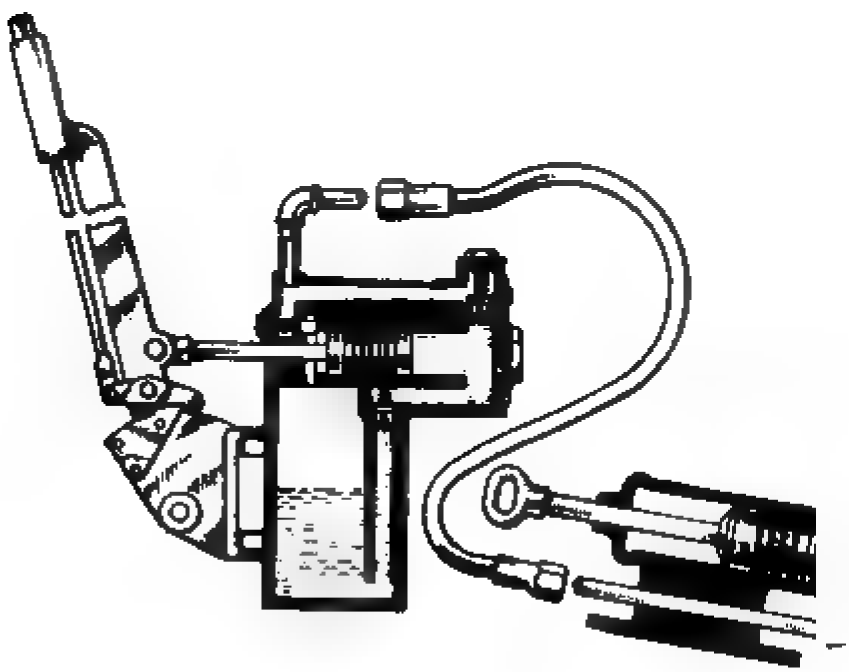


**Fig. 479. Layout of Hydraulic Brakes Used on Knox Tractor**
*Courtesy of Knox Motors Company, Springfield, Massachusetts*

more liquid from below without releasing the brakes. Then, when this extra quantity is forced through, the plunger is moved even farther forward, and the brakes applied more forcibly. The brakes are 20 inches in diameter by 6½ inches wide.

**Vacuum Brakes.** The latest development in the line of braking systems is the Prest-O-Lite vacuum brake. This brake consists of a controlling valve, a vacuum chamber, piping from the inlet manifold to the valve and thence to vacuum chamber, and a foot button or finger lever on the steering post to operate the valve and thus put the system into use. The rod in the vacuum chamber is connected up to the service brakes, the system thus taking the place of the usual pedal and foot operation. The chassis sketch, Fig. 480, shows this

in plan, *A* being the controlling valve, *BB* the tubing from the inlet manifold to the controlling valve and from it to the vacuum chamber *C*. The rod *D* from the chamber will be seen connected to the service-brake rods and levers.

In Fig. 480 the method of operating the system is not shown, but in Fig. 481 the foot lever can be seen with its connections. When this is pressed, the controller valve is opened and the engine, as it runs, draws air out of the chamber *C* in back of the plunger, gradually creating a vacuum, so that the plunger is forced to move forward to compensate for this. As the plunger carries a tail rod projecting through the end of the cylinder, and as this rod is connected up to the braking system, but with a big leverage, the movement of the plunger

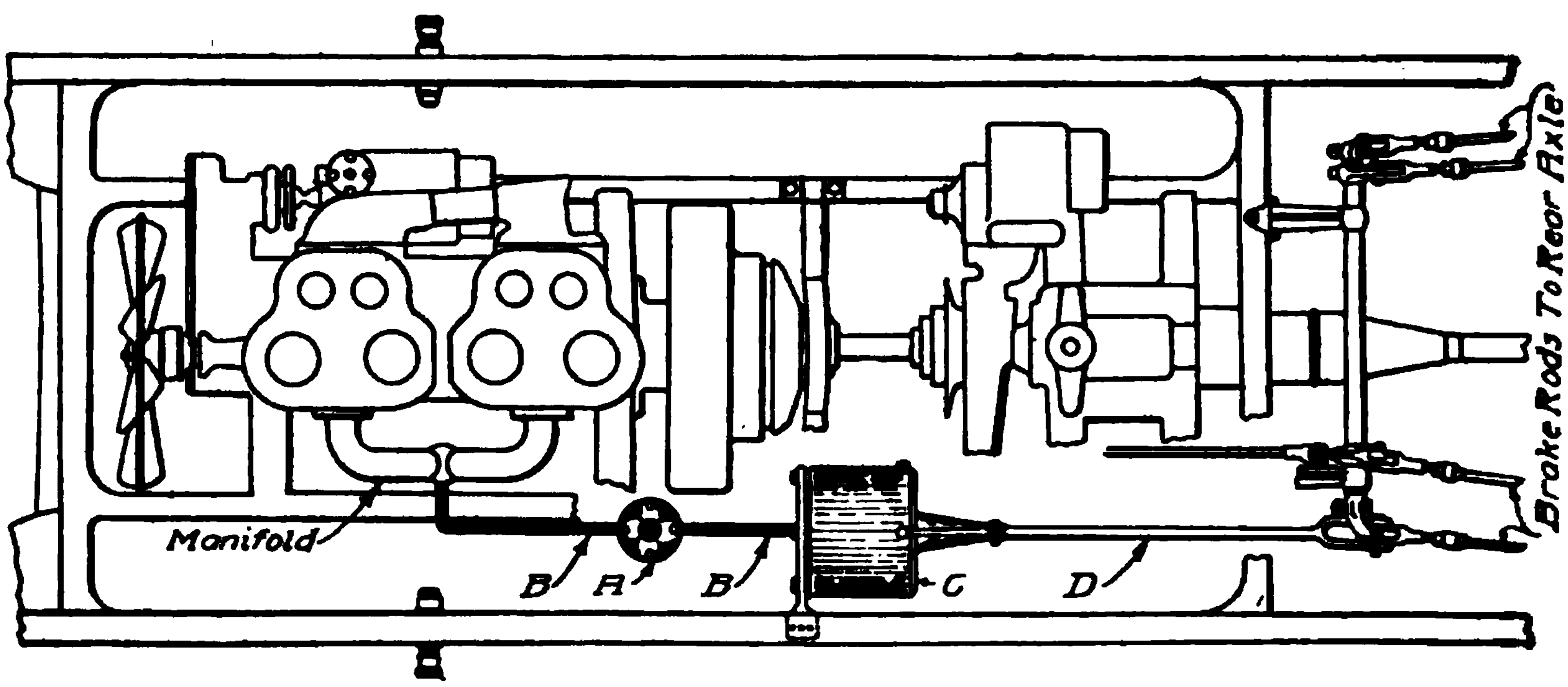



**Fig. 480. Chassis Plan Showing Application of Prest-O-Lite Vacuum Brake**
*Courtesy of Prest-O-Lite Company, Indianapolis, Indiana*

applies the brakes. The amount of brake application depends upon the amount of suction, and that is governed by the amount the valve is opened by the finger lever or foot button. Consequently, with this new brake, the bucking effort can be varied to suit the conditions.

It is said that the leverage arrangement is such that 10 pounds per square inch in the intake manifold will produce 1000 pounds braking effort at the rear wheels. This means that the brakes could be used with the engine running very slowly. The system is applied to the service brakes because a brake is sometimes needed when the engine is not running, as when coasting down a hill with the engine shut off and clutch out, or with the car standing and engine shut off, etc.; also because it is the most used system, and it is felt that the simple finger pressure and gradual or instantaneous application

possibilities of the new form make it more desirable as a service or running brake.

Whatever advantages may develop in the use of these special types, it is certain that the next few years will see considerable improvement in braking, so that a greater force may be applied more quickly, and thus act to prevent a large part of the accidents for which automobile owners and drivers are now unjustly blamed.

## BRAKE TROUBLES AND REPAIRS

**Dragging Brakes.** Probably the first trouble in the way of brakes is that of dragging, that is, braking surface constantly in

Fig. 481. Foot Button for Operating Vacuum Brake

contact with the brake drum. This should not be the case, as springs are usually provided to hold the brake bands off the drums. Look for these springs and see if they are in good condition. One or both of the brake bands may be bent so that the band touches the drum at a single point.

Another kind of dragging is that in which the brakes are adjusted too tightly—so tightly, in fact, that they are working all the time. In operating the car, there will be a noticeable lack of power and speed, while the rear axle will heat constantly. This can be detected by raising either rear wheel or both by means of a jack, a quick

lifting arrangement, or a crane, and then spinning the wheels. If the brakes are dragging, they will not turn freely.

All that is needed to remedy this trouble is a better adjustment. For the new man, however, it is a nice little trick to adjust a pair of brakes so that they will take hold the instant the foot touches the pedal, that they will apply exactly the same pressure on the two wheels, and yet will not run so loose as to rattle nor so tight as to drag.

**Dummy Brake Drum Useful.** Where a great deal of brake work is to be done, particularly in a shop where the greater part of the cars are of one make, and the brakes all of one size, a great deal of time and trouble can be saved by having a set of test drums. An ordinary brake drum with a section cut out so that the action inside may be observed is all that is necessary, except that it should be mounted suitably. As shown in Fig. 482, it is well to fit a pair of handles to the brake drum to assist in turning the drum when the adjustment is being made. The real saving consists of the work which is saved in putting on and taking off the heavy and bulky wheel each time when the adjustment is changed. The test drum is put on instead, and being small and light and equipped with handles, it is easily and quickly lifted on and off. This enables the workman to make a better and more accurate adjustment than he would when the heavy wheel had to be handled, while the cut-out section enables him to see the inside working also and thus correct any defects or troubles at this point.

Fig. 482. Dummy Brake Drum for Adjustment Work

**To Stop Brake Chattering.** It is claimed that the chattering of brakes is caused by having the brake lining, particularly of internal hand brakes, extend over too large a portion of the circumference of the drum. The result is that with a well-adjusted system, as soon as force is applied, the lining close to the operating cam and that on the opposite side close to the pin on which the brake shoes are pivoted jumps against the drum and then away from it. This jumping of the brake shoe, which is the result of too much lining, is

what causes the chattering. If the lining is cut away for about 30 degrees on either side of a line drawn from cam to pivot pin, as shown in Fig. 483, it is said that this chattering will stop immediately. If further trouble of the same kind results, bevel off the outside ends of the lining at the two 30-degree points.

Fig. 483. Method of Eliminating Brake Chattering on Internal-Expanding Brakes

A number of suggestions in the way of possible brake troubles, particularly on the side-by-side form of internal-expanding brakes, are indicated in Fig. 484. This shows a semi-floating form of rear axle with the two sets of brakes and operating shaft and levers. A number of suggestions are offered for this form, the most important of which is: "Renew worn brake lining and broken or loose rivets."

When a brake lining is worn, the proceeding is much the same as with a clutch leather, with the exception that whereas the latter


Fig. 484. Brake Troubles Illustrated

must have a curved shape, the former can be perfectly straight and flat. This simplifies the cutting; but most brake linings are made of special heatproof asbestos composition which is made in standard widths to fit all brakes, so the cutting of leather brake bands is not often necessary.

**Eliminating Noises.** Many times the brake rods and levers wear just enough to rattle and make a noise when running over rough roads or cobblestone pavements, but hardly enough to warrant replacing them. The replacement depends on the accuracy with which they work, the age and value of the car, and the attitude of the owner. In a case where the owner does not desire to replace rattling rods, the noise can be prevented by means of springs, winding with tape, string, etc.

If the rod crosses a frame cross-member or is near any other metal part, and its length or looseness at the ends is such that it can be shaken into contact there, a rattle will result at that point. This can be remedied or rather deadened by wrapping one part or the other. For this purpose, string or twine can be used as on a baseball bat or tennis racket handle, winding it together closely so as to make a continuous covering. Tire or similar tape may also be utilized. When this is done, it is necessary to lap one layer partly over the next in order to keep the whole tight and neat. It has the additional advantage of giving a greater thickness and thus greater resistance to wear. If none of these remedies are available or sufficient, burlap in strips or other cloth may be used, putting this on in overlapping layers the same as the tape.

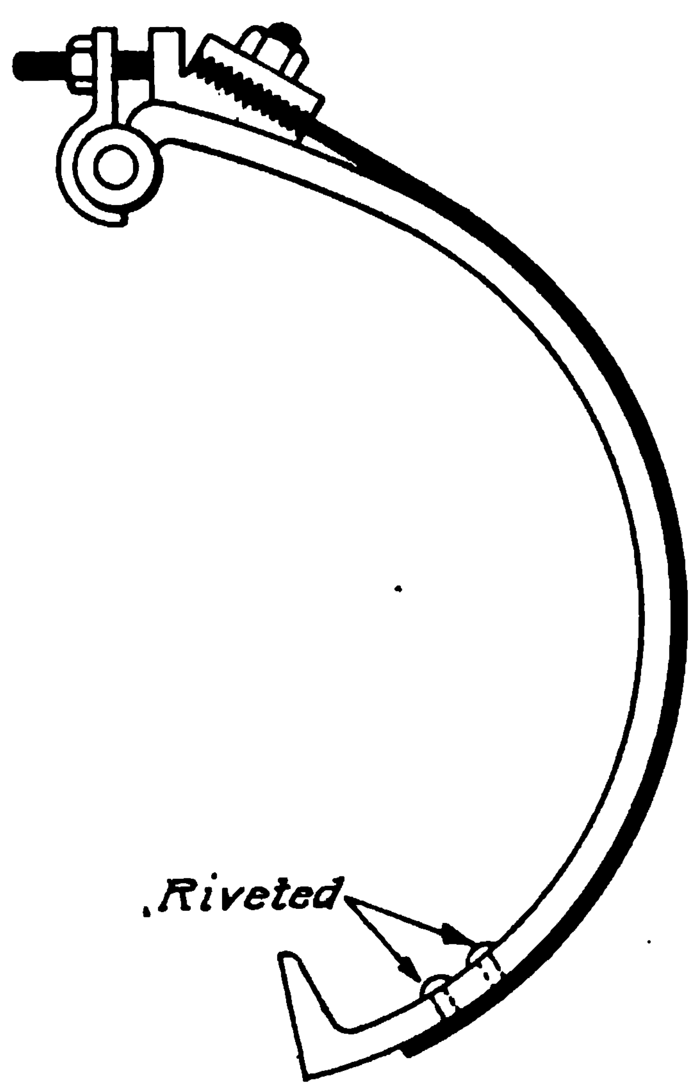


Fig. 485. Sketch Showing Method of Stretching Brake Linings before Attachment
*Courtesy of "Motor World"*

The springs should be put on in such a way as to take up the lost motion and hold the worn parts closer together. The rattle occurs when the movement of the car alternately separates and pulls together the two parts, a noise occurring at each motion. The spring should be put on so as to oppose this motion, acting really as a new bushing or pin, the pull coming first upon the spring and then upon the bushing or pin.

**Stretching Brake Lining.** Brake lining should be put on as tightly as possible, and the knowledge of this, combined with the

difficulty of doing it by hand, makes the stretching device shown in Fig. 485 particularly valuable when much brake relining is to be done. This is a simple pulling clamp, which is attached to one end of the lining after the first end has been riveted in place. Then it is attached to the end of the shoe, and the nut tightened so as to stretch it. When it has been stretched sufficiently, the other rivets can be put in, or the shoe and band with the stretches in place can be laid aside for a while to stretch it fully before fastening. Obviously, this is applicable only to the internal-expanding form, but the hook and clamp can be used on any size or type of expanding brake.

**Truing Brake Drums.** When both inside and outside surfaces of the brake drum are used, it is highly important that both be true. Since they do not stay that way long, the repair shop should be equipped to true them up quickly. A truing device is shown in Fig. 486, with the wheel and brake drum in place on it. One feature of the device is that brake drums need not be removed from the wheel. The device consists of a metal base having a strong and stiff wooden pier with a horizontal arm the exact size of the axle end mounted on it. The wheels are placed on the arm and rest on it the same as on the axle when on the car. The tool is double, with two ends, one of which cuts the inside surface of the drum, while the other cuts the outer surface. At the center this tool is attached to a heavy casting, bored out to slide over the shaft and with a key fitted into a keyway in the shaft to prevent the tool from rotating. The end of the arm is threaded, and a large nut with two long arms is screwed up against the tool at the start, and then it is used to feed the latter across the work.

Fig. 486. Apparatus for Truing Inside and Outside of Brake Drum in Place on Wheel
*Courtesy of "Motor World"*

This is subject to a number of modifications to fit it to the various sizes and shapes of brake drum. Another method is to use the lathe, provided the shop is equipped with a lathe large enough. By making a mandrel the same as the axle spindle and having a pair of dummy bearings to place on it, the brake drum can be slipped on to the mandrel, and the whole put right into the lathe. The surface, either internal or external or both, can then be trued up exactly as if the drum were on the axle.

## WHEELS

Broadly speaking, there are but two kinds of wheels according to the service each is to render, pleasure-car wheels and commercial-car wheels. The former may be further subdivided into wood, wire, and spring wheels; while the latter may be divided into wood, steel, and spring wheels. Some of the commercial vehicle wheels are further divisible, as steel wheels into sheet steel and cast steel; wood into spoked and solid; and spring wheels into various types.

**Wheel Sizes.** Wheels are used on automobiles, in combination with the tires, to afford a resilient and yielding contact with the surface of the road, so that people may ride with comfort. Therefore a wheel whose size is such as to yield the most comfort to the car occupants with due regard to its cost relative to the cost of the vehicle is the wheel to use. The cost of the wheels themselves, however, is so small in comparison with the cost of the pneumatic tires which are used on them as to be completely overshadowed by the latter.

Where comfort is sought as the prime requisite, cost becomes an accessory. The larger the wheel used the better the car will ride, and the greater will be the comfort of the occupants. This statement can be proved, although the gradually increasing sizes of wheels and tires as used on the best cars, both here and abroad—advancing from the early 26 and 28×3-inch tires, to as high as 38×5½-inch tires, and freaks up to 48×12-inch—should be sufficiently convincing.

*Advantages of Large Wheels.* A graphical demonstration of the difference between the action of the large and small wheel to the advantage of the former is shown in two drawings, Figs. 487 and 488. Fig. 487 presents the case of wheels passing over a common brick 4 inches wide by 2 inches high, and Fig. 488 shows the action in passing across a small rut in the surface of the road, 8 inches wide

by $1\frac{1}{4}$ inches deep. In both cases, *A* shows the 28-inch wheel and *B* shows the 40-inch wheel. Both instances, too, have been selected at random, and not so chosen as to favor either wheel. It would have been possible to so select the sizes of both obstruction and depression as to make out a stronger case.

The height of the brick being 2 inches the wheel must rise that distance, whatever its diameter, but in the case of the 28-inch wheel, this rise of 2 inches is largely relative to the wheel diameter being one-fourteenth, or 7 per cent. In the case of the larger wheel of 40-inch diameter, the rise is again 2 inches, but it is now one-twentieth of the wheel diameter, or 5 per cent. In the case of the

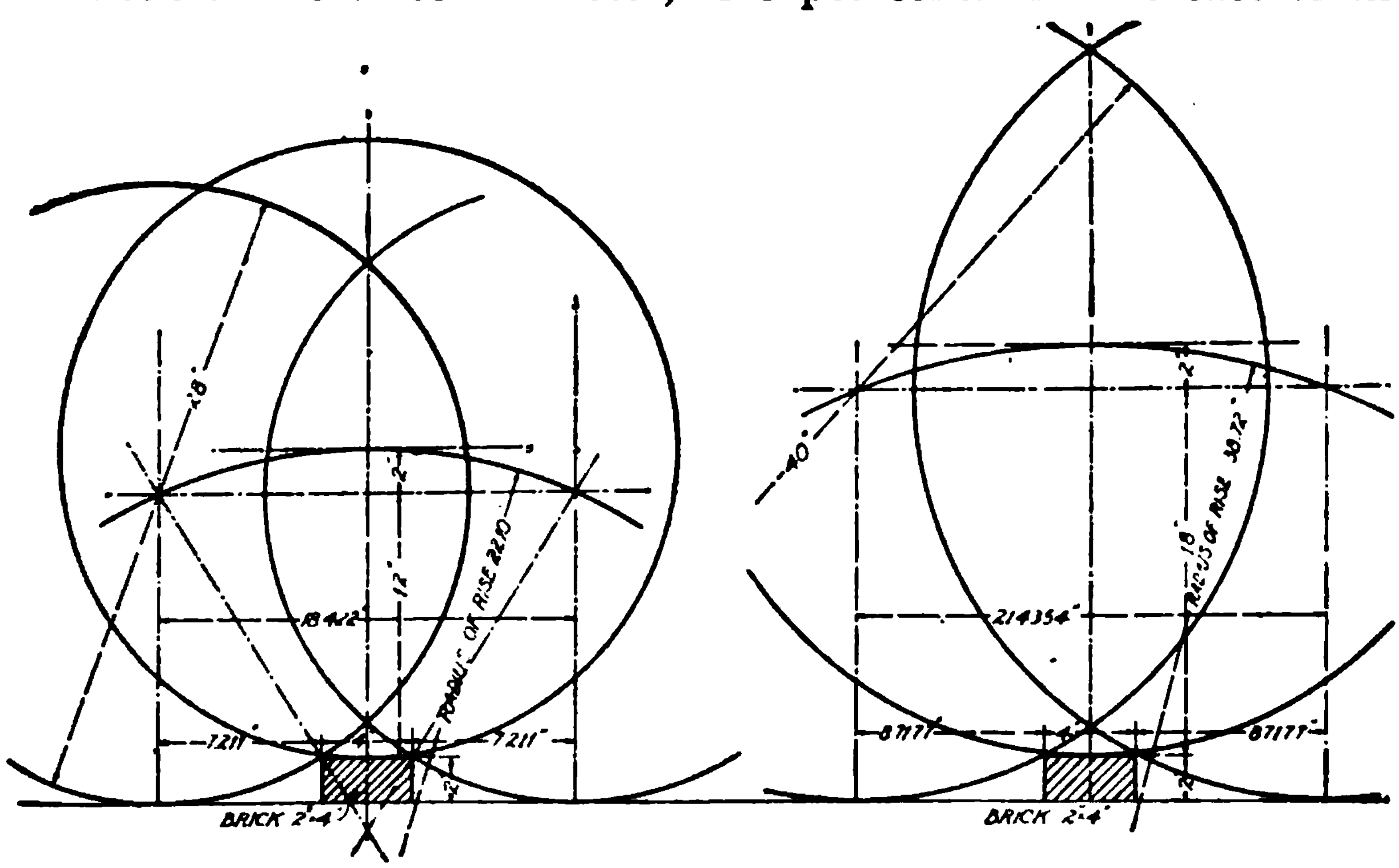



Fig. 487. Diagram Showing Advantage of Large Wheels in Passing over Obstruction

smaller wheel, the rise is distributed over a length of about 18.43 inches from the moment when the forward edge strikes the obstacle to the moment when the last part of the tire leaves the last edge of the brick. If this rise were evenly distributed over this distance, rising as an arc of a circle, its radius would be slightly over 22 inches.

Considering the 40-inch wheel under the same circumstances, it performs the act of rising and falling 2 inches in the longer distance of about 21.5 inches, the radius of this rise being 38.75 inches. It is obvious that the latter is a much easier rise than the former, the lift being distributed over a length 16 per cent greater. Similarly, with the descent from the high point to the surface of the road again,

this more gradual rise and fall convert the surmounting of the obstacle from a sharp upward bump and downward jounce into an easy and not unpleasant swinging up and down.

A drop into a hole, as illustrated by Fig. 488, shows the beneficial effect of the large wheel better, perhaps, than does the rolling over a rise. A rut in the road 8 inches across, into which the two wheels drop in passing, is shown. At *A*, the 28-inch wheel is seen to drop the considerable amount of $\frac{9}{16}$ inch, while at *B* the 40-inch wheel drops but $\frac{3}{8}$ inch into the same hole. Evidently the larger wheel has an advantage in so far as passing over obstacles or holes is concerned.

Again, on account of its larger radius, the arc of the larger wheel is flatter and has more length of tread in contact with the

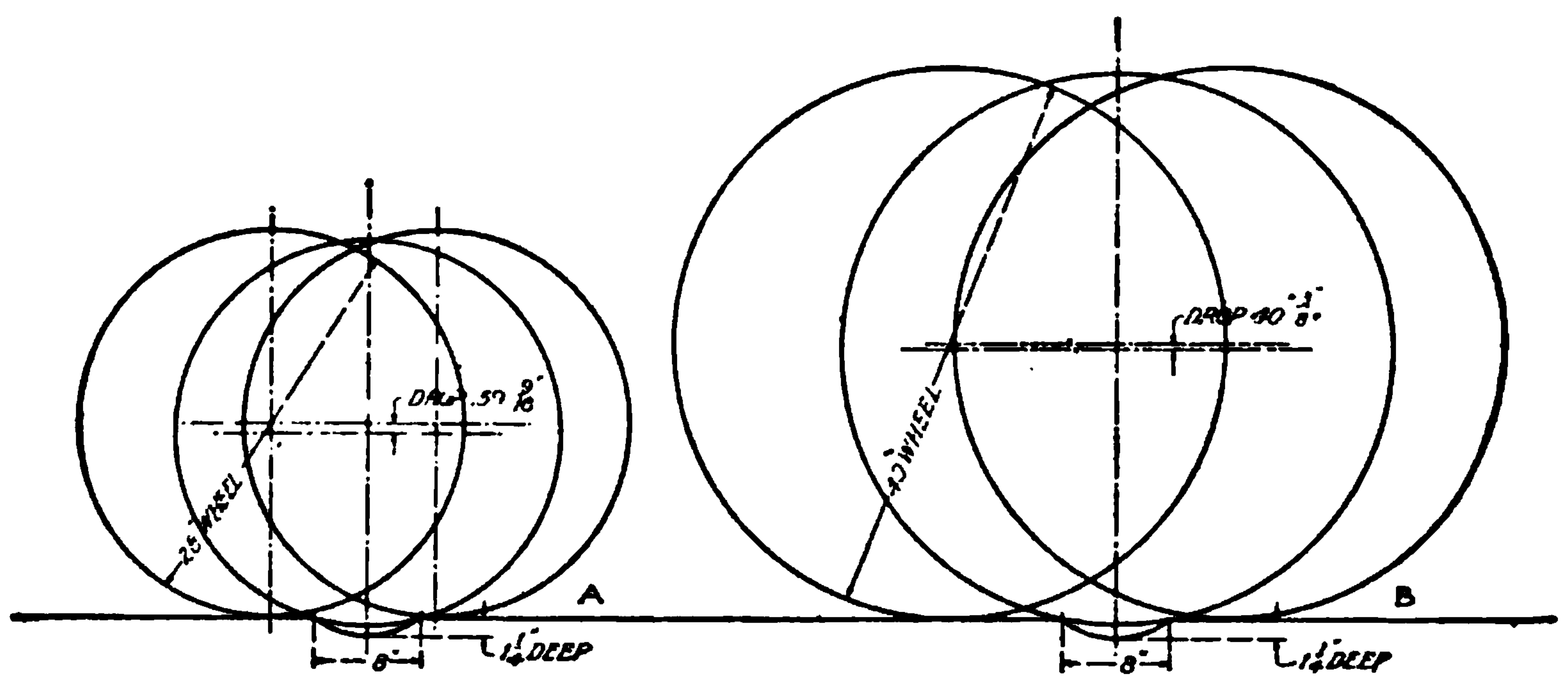



**Fig. 488. Diagram Showing Advantage of Large Wheels in Passing over Depression**

surface of the ground, this being particularly noticeable on rough roads. Not alone does this mean added adhesion to the ground and thus lessening driving effort to propel the same car, but it also means a greater resistance to side slip or skidding, thus conserving the power and increasing the safety of the occupants. Other arguments could be offered in favor of large tires for easy riding, but those given should suffice.

## PLEASURE-CAR WHEELS

**Wood Wheels.** Wood wheels are the most common form for pleasure cars in this country, being almost universal. Ordinarily, they are constructed of an even number of spokes, which are tapered at the hub end and rounded up to a small circular end with a shoulder at the rim, or felloe, end. Fig. 489 shows this construction, *A* being

the felloe on which is the rim $B$, and $R$ is the spoke which, at the hub end, tapers down to the wedge-shaped portion $P$. This matches up to the wedge-shaped ends of the other spokes, so that when the wheel is assembled they form a continuous rim around the central or hub hole.

The spokes are held at their inner ends by metal plates and by through bolts, which are set at the joints between the spokes so as to pass equally through each spoke, as shown at $D$. Not only do these bolts hold the spokes firmly to the wheel, but they have an expanding, or wedging, action tending to make the center of the wheel very rigid.

Fig. 489. Construction of Wood Wheels

The outer end of the spoke has a shoulder $E$ and a round part $C$, which fits into a hole bored through the felloe. To prevent the felloe coming off after the spoke is in place, the spoke is expanded by means of a small wedge driven into it from the outside, as shown at $F$. In this way, the wheel is constructed from a series of components into a strong rigid unit.

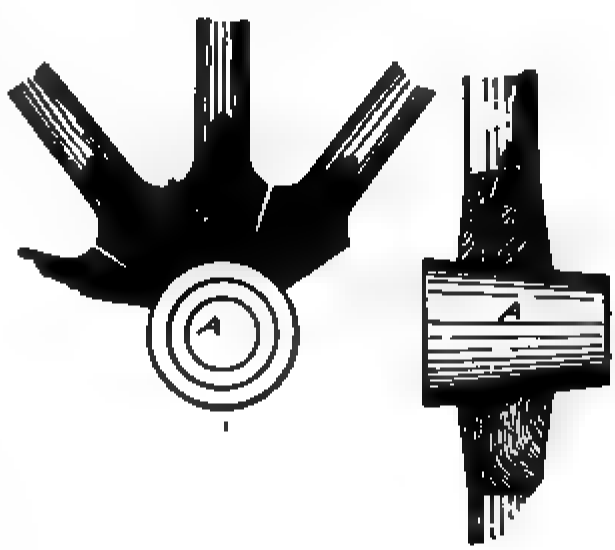



Fig. 490. Method of Tightening Spokes of Wood Wheels

Such wheels wear in two places, at the inner and at the outer ends of the spokes. The remedy in the latter case is to withdraw the small wedge and insert a larger one in its place. At the hub end, when wear occurs, this, too, must be taken up by means of wedges. Fig. 490 shows a method of doing this when the hub has no bolts at the joints. A false steel hub $A$ is driven into the hub hole, after which wedges of steel are driven in between the wedge-shaped ends of the spokes. For slight cases of wear and squeaks, the wheel may

be soaked in water, which will cause it to swell, taking up all of the space.

There are various modifications of this, nearly all of them changing the hub end of the spoke. In the Schwartz wheel, a patented form, each spoke is made with a tongue on one side of the wedge-shaped part and a groove on the other. In assembling the wheel, the tongue of each spoke fits into the groove of the spoke next to it, thus rendering the whole hub end of the wheel, when assembled, a stronger unit, being stronger in two directions, one of them of more than ordinary value. In driving the tongue into the groove, the wheel is rendered strong in a radial direction, but, when the wheel

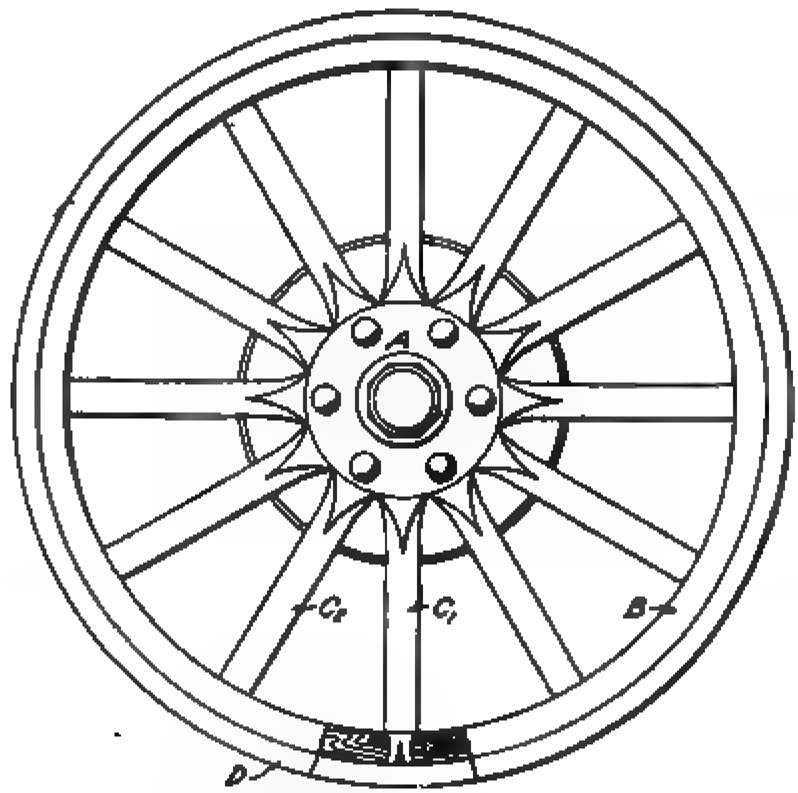



Fig. 491. Details of Wood Wheels with Staggard Spokes

is entirely assembled, the tongue-and-groove method leaves it very strong to resist side shocks, a point in which the wood wheel is weakest.

*Staggered Spokes.* As mentioned above, the wood wheel has little lateral strength, nor can it ever have, from the very nature of its construction, except in unusual cases, like the Schwartz patent wheel just described. A method of increasing the lateral strength somewhat is that of using staggered spokes, these being alternately curved to the outside and to the inside, as shown in Fig. 491. This gives one set of half the spokes forming a very flat cone with its apex, or point, at the inner side of the hub, while the others form another cone with its apex at the outside of the hub. Each one of

these conical shapes is stronger to resist stresses from the side on which the point is located than would be the same number of spokes set flat. Hence, the staggered-spoke wheel has the advantage over the ordinary type in that it has greater strength from both sides. In the figure, $A$ is the iron hub, $B$ the felloe, $C_1$ the right-hand and $C_2$ the left-hand spoke, and $D$ the steel rim for the tire. This is a 12-spoke wheel, 6 of the right-hand spokes $C_1$ and 6 of the left-hand spokes $C_2$. The section shows how these pass alternately to the one side or to the other, forming the strong cone shape.

Fig. 492. Section of Steel and Wood Wheel

Fig. 493. Complete Steel and Wood Truck Wheel

Another method of handling this problem in a somewhat similar manner is the use of double sets of spokes, the spokes, however, being in two different planes separated a considerable distance at the hub. Of a necessity using the same felloe, the outer ends must be in the same plane. Fig. 492 shows a drawing representing a section through the center line of the wheel, while Fig. 493 shows a photographic reproduction of it.

In Figs. 492 and 493, $A$ represents the steel rim on the felloe $F$, the latter being of metal in this case, as is also the wheel so it

may be disassembled. The spokes $R$ have a tubular end piece of metal $G$, which is set over the rounded end of each spoke and fits into a hole in the felloe. $I$ and $S$ are, respectively, the inner and outer parts of the hub, which are held together and to the spokes by means of the bolts $N$. Z is the hub cap, while $U$ and $V$ are filler pieces aiding in the dismantling process. The strength of the wheel is self-evident, but it is difficult to see the advantage of the disassembling feature, as a stress or strain which would break one spoke, would, in almost every case, break practically all of the spokes, thus necessitating a new wheel instead of new spokes.

**Wire Wheels.** Many of the little details of the automobile were inherited from its predecessor, the bicycle. Among these may be mentioned the wire wheel. Practically all bicycle wheels were and are of the wire-spoked type, and this same form of wheel was used on all earlier automobiles. It had no strength in a sidewise direction, nor did it, in fact, have much of anything to recommend it except its light weight. For this reason, it failed in automobile service, and received a setback from which it has even now not wholly recovered.

Fig. 494. Hub Details of Bicycle Wheel

*Early Bicycle Models.* Fig. 494 shows an early type of wire wheel for automobiles, its construction indicating clearly its bicycle ancestry. The spokes were set into a casting, which formed the hub, and into the steel rim by means of a threaded sleeve, the head on each end of the spoke resting on the inner end of the sleeve. The sleeves were screwed in and out to adjust the tension of the spokes. This tension was usually considerable, thus reducing in part the ability of the wheel as a whole to resist side stresses, for the piece already in tension could not be expected to sustain additional tension, or compression, or a combination of either with torsion, according to the way the force was applied. Then, too, the casting for the hub was wholly unsuited to resist stresses, and the distance apart of the spokes at the hub was not sufficient, making the cone so very flat that it had very little more strength than a perfectly flat wheel.

Following the failure of wire wheels, there was a rapid change to wood wheels, which were almost universal for several years. Soon after this change was made, there was an increase in the size and power of automobiles, which, in turn, was followed by a demand for lessened weights. In the meantime, makers of wire wheels, knowing their faults, began to re-design in order to eliminate them. Their success is best evidenced abroad, where about one-half of the French and more than two-thirds of the English cars, in addition to over seven-eighths of the racing cars in both countries, are now equipped with wire wheels.

*New Successful Designs.* This result has been brought about by a realization of the previous defects and their elimination. Thus, no more cast hubs are used, drawn or pressed steel of the highest quality and greatest strength being used instead. The spokes have been carried out farther apart at the hub, obtaining a higher cone and thus a stronger one. Spoke materials are better and stronger, besides being used in greater quantities, that is, larger spokes and larger numbers of spokes per wheel, in some cases a triple row of spokes being used in addition to the ordinary two rows. This additional row acts as a strengthener and stiffener much like the diagonal stays on a bridge. Fig. 495 shows a set of double-spoke wire, triple-spoke wire, and interchangeable wood wheels side by side for comparison, while in Fig. 496 is presented a recent triple-spoke front wheel in detail.

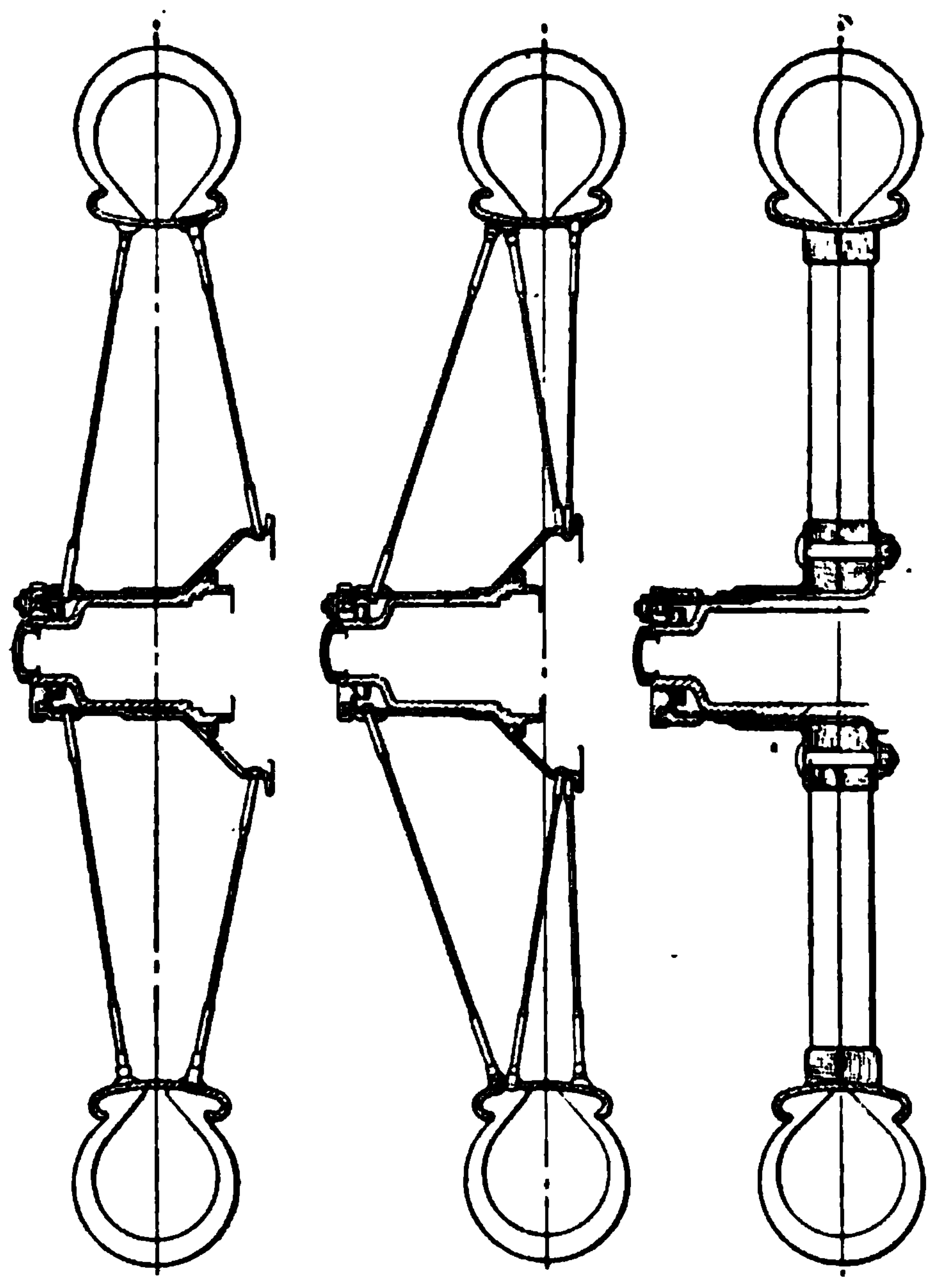


Fig. 495. Sections of Double and Triple Steel and Wood Spoke Wheels

In the former figure, the relative depths of the various cones and their corresponding strengths are made evident, being side by

side. In this comparison, it will be noted that the new triple-spoke wheel has a much longer outer cone than the double-spoke wheel, while, on the other hand, the inner cone has been flattened. The triple spoke has a greater depth, considering the set of them as an additional cone, than has the inner cone in the double-set wheels.

In examining closely the older double-spoke form and the newer triple type, it will be noted, also, how the wheel itself, or rather the tire and rim, have been brought closer in to the point of attachment, thus rendering the whole construction stronger and safer. In Fig. 495, it will be seen that the center line of both tire and rim passes midway between the inner and outer ends of the hub on double-spoke wheels, while on the triple form it is even with the inside end of the inner hub, being, in fact, farther in than is the case with the wood wheel. One thing will be noted in all these spokes, regardless of number, position, or inclination, and that is that their ends present a straight head. On the older bicycle spokes, the diagonal-spoke head was a great source of weakness, tending to create failure at the outset. The modern wire wheel is so constructed as to do away with this fault. By actual tests, the wire spoke—not the stronger triple spoke but the double spoke—has been found to have the following advantages: lighter weight for the same carrying capacity; greater carrying capacity for equal weight; superior strength from above or below in the plane of the wheel; lower first cost (it is doubtful if this will hold good for the newer triple-spoke forms); and, in addition, tests have proved superior strength in a direction at right angles to the plane of the wheel. So marked is the difference in weight of the two that five wire wheels are said to be lighter in weight than four wood wheels of equal carrying capacity.

Fig. 496. Details of Triple-Spoke Front Wheel

All these arguments in favor of wire have been built up one by one, for much prejudice had to be removed. In spite of this, however, the wheel is slowly but surely building up a reputation and a long list of friends. Since, even now, England and the Continent continue to set the fashion in automobiles, it is not too much to expect to see wire-spoke wheels in common use in the United States in a few years. In fact, the dozen manufacturers offering this wheel in 1914, with ten more giving it as an option, have been increased to about forty who are fitting it regularly, with perhaps fifty or more offering it as an option in 1915. In fact, almost any car maker in the country will fit wire wheels for a slight additional charge.

For 1917 some 20 odd makes of cars are offered with wire wheels as regular equipment, and about 25 more offer this as an option without extra charge. As there are about 190 cars on the market, the former represents 10.5 per cent, and the latter 13.2 per cent of all makes; the two together total 23.7 per cent, or less than one-quarter. However, these figures do not quite indicate the relative popularity of wire wheels.

*Wire Wheels Much Stronger.* The increase in the use of wire wheels has been brought about by better designs; greater attention to the details of manufacture, assembly, and use; but primarily by the greater strength which has been built into the wire wheel. One way in which this has been done is by rearrangement of the spokes as, for instance, the triple-spoke form just described and shown in Fig. 469. Another and later form is the quadruple-spoke wheel as seen in Fig. 497. This is made and sold by the General Rim Company, Cleveland, Ohio, and is called the G-R-C wheel. As the sketch indicates, it has all the features of demount-

Fig. 497. G-R-C Quadruple-Spoke Wire Wheel

ability, etc., of other wire wheels, the notable differences being the spoke arrangement to give strength and the form of rim—a patented form to be described in detail later.

By comparison with Fig. 496, it will be noted that a double triangular section is formed in the G-R-C, the inner spokes forming the inside of the hub and the outside of the hub forming one triangle, while the outer spokes from each form the other. In Fig. 496, it will be noted that there is but the one triangle and a straight row of spokes.

**Sheet-Steel Wheels.** The sheet-steel wheel is really a form of wire-spoke wheel, with an infinite number of spokes joined together. It has many advantages, some of which might be mentioned as follows: strength, lightness, low first cost, low cost of maintenance, and cleanliness. To take them up in order, the strength of two steel plates set a few inches apart in a somewhat triangular form with the base toward the hub and well attached at the center and at the rim of the wheel, is self-evident. Aside from the natural strength of the steel plates—far in excess of the wire spokes—or round wood spokes, there is the strength of the triangular form. A strong connection at the top and at the bottom makes the whole construction very similar to a structural form. This shape closely resembles a box girder, having great resisting strength in all directions.

The light weight of the steel wheel comes from the thinness of the steel plates which are used, and similarly from the thin and light connecting members, either top or bottom. In Fig. 498 the junction at the top is seen to be nothing more than the steel rims for the tire, thus doing away with the usual felloe or substitute for it. In this figure, the wheel is seen to consist of the hub made with two flanges, to which the side sheets are bolted; the brake drum *I* bolted to the sheet on the inside, midway up its height; the steel rim mentioned before; and the bolts and rivets necessary to join the parts. At the hub, bolts are used to allow of dismounting the sheets in case of damage, for replacement or otherwise. At the rim, however, the plates are riveted to the rim, and riveted together.

Low first cost is brought about by the simplicity of the wheel. The wheel consists of the usual rim, not counted in the wheel cost, and two pressed-steel sheets flanged at the top, with a few holes punched in them. These sheets are very cheap to make, while the

hub construction is much cheaper than the ordinary hub, for the reason that there are usually two parts where this construction requires but one, and this a very simple one needing little machining. Low maintenance cost is brought about by the rigidity of the whole construction; the few parts, which make few to replace or even to wear; the cheapness of these parts, when replacement is necessary; and the well-known strength and long life of sheet-steel plates.

On the score of cleanliness, it may be said that this is one of the drawbacks of the wire-spoke wheel, cleaning between and around

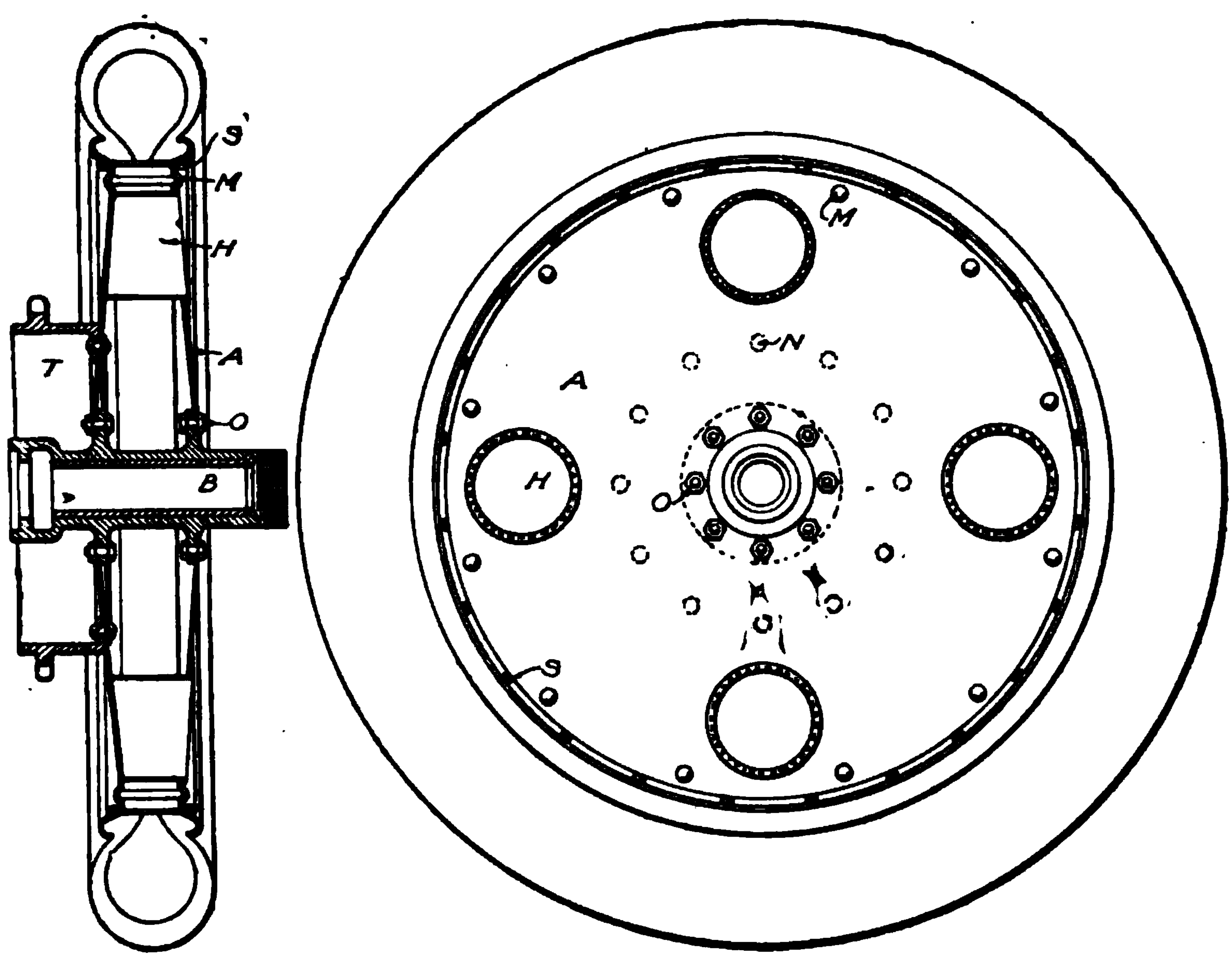



Fig. 498. Side and Sectional Views of Sheet-Steel Wheels

the spokes being very difficult, if not actually impossible. The large number of spokes makes the hub inside of the spokes impossible to clean, whereas, with the sheet-steel wheel, the cleaning consists in merely turning a hose on the sides of the wheel, the cleaning of the hub being entirely unnecessary.

It will be noted, too, in this illustration that the wheel has considerable spring, or should have, in a vertical direction. It is claimed for this type of wheel that this springiness is an added advantage as it allows the use of solid or cushion tires, and thus

eliminates the troublesome pneumatic tire with its puncture and blowout possibilities. For commercial-car use, all of the advantages just mentioned are of double worth, for which reason the steel wheel is making great strides forward on commercial cars. Where the springiness of the wheels is not so desirable as strength, the sheet-steel plates may be replaced with either pressed- or cast-steel side members on which strengthening ribs are formed. The sides of the wheel have holes *HH* through them which are provided for ventilation, to decrease the weight of the side sheets, and to lessen the wind resistance to the wheel when moving rapidly. In some steel wheels these holes are omitted; in others a larger number than the four shown here are used. Fig. 499 gives a better idea of the general appearance of the wheel ready to use, being lettered the same as Fig. 498. The spokes shown in Fig. 499 are painted on the smooth exterior of the plates, but in other wheels these spokes are formed in the plates as previously mentioned.

Fig. 499. Sheet-Steel Wheel Complete

*Steel Wheels Designed for Cushion Tires.* Sheet-steel wheels, particularly those of very thin sheets, have a certain amount of springiness, this being utilized with solid and cushion tires on the assumption that the wheel will absorb the vibrations set up by the road inequalities. In Figs. 500 and 501, a wheel is shown which was designed for this express purpose. The wheel is called an elastic wheel and uses solid tires.

By means of the figures the construction is made clear, the wheel consisting of two halves, one a single sheet of metal attached to the hub and forming its own rim portion, and the other a section which consists of two sheets, one attached to the hub and forming its own rim portion, with another additional plate riveted to it near its outer

end and attached to a middle flange on the hub. The two outer members of themselves would be very springy and consequently very weak, being of very thin metal. The diagonal extra sheet stiffens the whole construction, besides adding 50 per cent to its side strength. This is also of thin metal, so the whole wheel retains some springiness.

**Parker Pressed-Steel Wheels.** One fault with all the steel and sheet-steel wheels mentioned was that they did not resemble other wheels, consequently the people did not want them. Moreover, in many cases, their construction did not adapt them to the use of regular tires but, on the contrary, called for special and expensive forms. However, none of these drawbacks are present in a new form of pressed-steel wheel, Fig. 502. Upon close inspection it will be seen that this wheel has no felloe in the ordinary sense, the rim of the wheel forming the only felloe. In this respect, the wheel is an outgrowth of the former Healy demountable rim, the

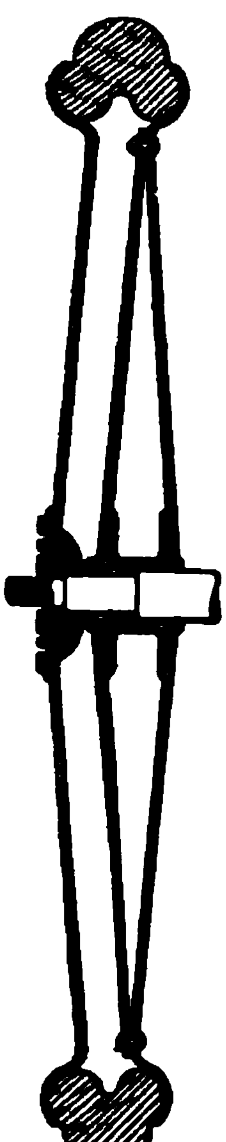


Fig. 500. Steel Wheel

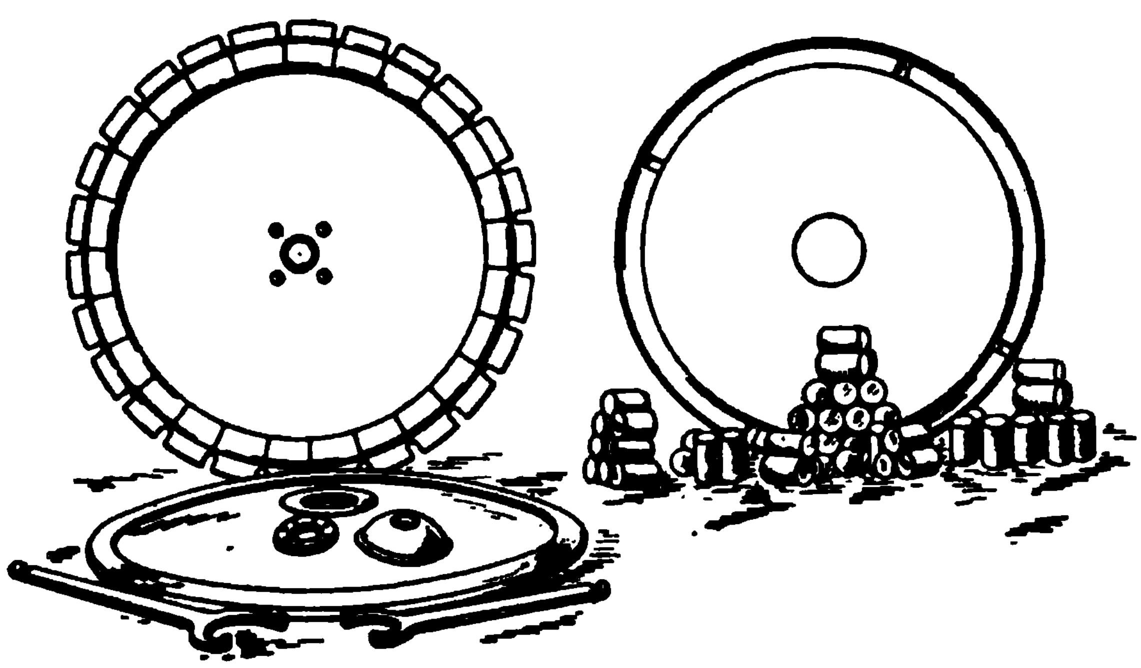


Fig. 501. Disassembled Steel Wheel

modern form being a combination of a demountable rim with steel spokes. This wheel is suitable for any car, the hollow steel spokes having great sustaining power. It is interchangeable with all ordinary wood artillery wheels of the same size, and fits between the usual hub flanges. The spoke portion is made as a pair of units, each forming half of all the spokes, the two being welded together. When finished in this manner, they have half the weight and more than twice the strength of the wood wheel, the greatest saving being at the rim, by the removal of from 60 to 100 pounds of metal and wood.

This wheel takes the ordinary demountable rim directly upon the ends of the spokes, the one shown being the No. 2, which is suit-

able for about twelve different rims as made by the largest manufacturers. The No. 1, whose only difference in appearance is a flat spot just under the bolt heads at the ends of the spokes, takes all one-piece clincher or straight side rims, whether clincher or Q.D. (quick detachable). The wheel shown is a 36- by $4\frac{1}{2}$-inch size, made from .083-inch sheet steel, with ten spokes $1\frac{3}{4}$ inches round and a center portion, all of the same thickness of steel.

A number of other pressed-steel wheels, made, like the Parker, by pressing out two or more simple units, and welding these together, are making their appearance. These show great ingenuity and variety in the methods used to produce this same result and yet avoid the Parker patents. This form of wheel, having the appearance of wood, yet with greater strength and dependability and also of lighter weight, may perhaps be the final answer to the wheel problem; certainly this is possible if quantity production can bring them down below the price of wood wheels, which now seems apparent.

Fig. 502. General Appearance of Parker Hydraulic Steel Wheel

## COMMERCIAL-CAR WHEELS

**Requisites.** On commercial cars the service is so different as to call for entirely different wheels. Of course, many commercial-car wheels are nothing but pleasure-car wheels with heavier parts throughout, but it is coming to be recognized that heavy trucks, tractors, and similar vehicles should have their wheels designed for the service required of them the same as lighter cars. No springiness or resiliency is required for heavy truck service, but simply these three things: strength to carry load and overloads; strength to resist side stresses; and such material, design, and construction as

will make for low first cost and low cost of maintenance. A fourth desirable quality might be added to these, the quality of being adaptable or adapted to the tires to be used.

**Wood Wheels.** Taking Fig. 503 as an ordinary heavy vehicle wheel, let us see in what ways it fulfills or falls short of these requirements. The spokes are large in both directions and widened out at the felloe to give greater side strength. The felloe, which cannot be seen, may be judged as to size from the width and location of the dual tires, which would indicate great width and considerable thickness. This style of tire calls for a steel band shrunk over the felloe, while the heads of the cross-bolts show how the tires were put on and held on. All these make for great strength in both horizontal and vertical directions, and all parts except the spokes are simple to make, and even these are simple for the wheel manufacturer whose shop is rigged to make them. Moreover, to fill the last requirement, the wheel is adaptable to this tire or to any one of a number of motor-truck tires which might be used.

Fig. 503. Double-Tire Wood Truck Wheel

A slight variation from this is the double-spoke wheel, in which the spokes, in addition to being placed in double rows, are set so as to miss each other across the wheel, that is, each spoke of one row coming between two of the other. This placing allows the spokes to be made larger and stronger than in the ordinary case, while the double rows have the same strengthening effect as the tapering of spokes. The hub portion is assembled as two separate wheels, so that the work of assembling as well as of making the parts is slightly more than with the ordinary wheel. This is more than compensated

for by the added strength. It is but fair to state that each of the last two wheels described is of English make.

In all wood wheels, the blocks composing the wheel and tire are of well-seasoned rock elm, sawed into wedge-shaped blocks, with the fiber lengthwise. The blocks are glued and nailed together until they form a circle. They are then turned round and to size in a large wood lathe, a shoulder ½ inch wide being formed at the same time on each side of the tire 2.5 inches from the tire surface. A heavy steel ring with a corresponding shoulder is then shrunk

Fig. 504. White Cast-Steel Wheel

over the wood shoulder on each side of the tire, drawing it together much like the ordinary steel tire on a wood wheel of a carriage. Bolts are run through these rings and through the wood blocks from side to side to prevent the blocks from splitting sidewise. To increase the life of this tire, steel wedges ¼ inch thick are driven crosswise into the face of it 2.5 inches deep around the whole tire about 3 inches apart. These wedges prevent the tire from slipping; in fact, they act like an anti-skid chain and do not harm the pavement, being set flush with the surface of the wood blocks.

It is said that one set of these tires was used for nine months, and at the end of that time they were still good for service. The tires reach clear to the hub, thus doing away with spokes and enabling the tires to be slipped over the hub and held in place by a removable flange bolted through the wood to the fixed flange on the opposite side of the hub.

**Cast-Steel Wheels.** The heavier the service the more unsuitable do wood wheels become, that is, wood-spoke wheels. For many five-ton trucks, practically all seven- and ten-ton trucks, and nearly all tractors, the cast-steel wheel is used, either spoked or solid, the spoked form being given the preference. Fig. 504 illustrates a spoked cast-steel wheel, fitted with a solid tire. The wheel is cast with ten heavy ribbed spokes, a ribbed felloe, and a grooved-felloe surface, into which the tire is set.

**Miscellaneous Wheel Types.** *Steel.* Steel wheels are gaining for heavy truck use, and a number of the better steel-casting firms are now getting into this work, with the result that better steel wheels are becoming available.

Other constructions, such as steel and wood combination wheels with removable and replaceable spokes, and the like, are rapidly going out of existence. Truck work is unusually severe, and it takes but a few weeks of actual use to show up any of the so-called freak wheels. The simplest seems to be the best, the only question at present being whether the material shall be wood or cast steel. Pressed steel may offer some opportunities in combination with welding, since good work has been done on pleasure-car wheels of this type.

*Spring Wheels with Longitudinal and Tangential Springs.* Spring wheels for both pleasure cars and trucks have not proved to be all that was claimed for them. For pleasure-car use they have gone out entirely; for truck use they are restricted to the smaller and lighter sizes, as the 1½- and 2-ton sizes driven at high speeds in city work. On these sizes, one or two well-designed forms are giving good service. The cherished dream of putting the pneumatic tire out of business through the medium of the spring wheel is still a dream.

When longitudinal springs are used to do away with the alternations of stresses peculiar to the radially disposed springs, the appearance of the wheel is much altered, as Fig. 505 shows. This

wheel consists of an inner wheel, having its own spokes—ten in number—and its own felloe. To the felloe are attached by means of bolts V-shaped arms, which hold one end of a series of spiral springs, the other end of each of the springs being held in a similar V-shaped arm bolted to the opposite side of the outer felloe carrying the tire. There are eighteen of these springs in two sets of nine each. Those springs which have their near end fastened to the near side of the inner felloe have the far end fastened to the far side of the outer

Fig. 505. Seatoh (American) Spring Wheel

felloe, while those attached to the far side of the inner felloe have the other point of attachment on the near side of the outer felloe.

When the wheel strikes an obstacle, a twisting action is set up, the outer felloe and tire moving while the inner felloe and axle remain stationary. This twisting of the springs tends to coil them tighter, which results, when the obstacle is passed, in the springs untwisting and turning the outer felloe and tire backward as far as it was previ-

ously moved forward. Since, however, the springs have a certain amount of stiffness in their coils, and the wheels do not rise and fall relative to one another, except in so far as the twisting action is concerned, it follows that considerable shock must be transmitted to the axle and thus to the body and its occupants. This wheel, therefore, while possessing strength to resist side stresses, does not give the smooth riding qualities so much desired.

A wheel very similar in appearance and action but with the wood spokes eliminated has been used very extensively in the last few years by the express companies and other big users of motor trucks. Starting with a few of them on front wheels, they have saved tires and tire money to such an extent that the companies have added more and more. Next they were tried on rear wheels. Seeing the good results obtained by the big companies with these wheels, many smaller firms and tradesmen with only one or two trucks have adopted them. They take a small size solid tire in place of a very large pneumatic and are said to cut the tire cost from one-half up to two-thirds and more. While used mainly for vehicles carrying a 1-ton load, they have been tried successfully on 2-ton vehicles.

Fig. 506. Diagram of Action of Taylor Spring Wheel

It is in this class of service—the lighter vehicles for smaller firms—where every item of expense must be watched very carefully that the resilient wheel should show the best results. For heavy work, there seems little future for it.

A form of wheel which comes somewhere between the two just mentioned, having some side strength and easy-riding qualities, while at the same time participating in part of the principles of both those described, is that shown in Fig. 506, which is a diagram showing the construction. This consists of spiral springs used not radially nor longitudinally, but tangentially. Moreover, the springs are not

attached directly to the hub, but to levers pivoted on an outer, or false, hub. When an obstruction is met with, so that the tension of the springs is altered, the springs act upon the levers and thus turn the false hub about the real inner hub by an amount corresponding to the character of the obstruction. This eccentric motion of the outer hub, induced by the spring action, takes up the shock of the road obstruction much as does the wheel shown in Fig. 505.

The construction is such as to allow of the springs being covered by means of a water-tight case, which will protect them from the elements and thus lengthen their life. This is a good feature which is lacking in all other wheels thus far shown.

*Spring Wheels with Flat Spiral Springs.* The flat spring bent into a semicircular or spiral form is little used for spring wheels. There is a double reason for this; they lack every desired quality, unless it be side strength. If stiff enough to handle considerable load, they are heavy, they are slow acting, and their action is long continued; if made light, they act too much and the vibrations are long drawn out. Moreover, if few springs are used, the breaking of a single one puts the wheel out of use; if many are used, the wheel becomes very heavy.

While a number of flat-steel spring wheels have been constructed both here and abroad, they have not been uniformly successful, as has been pointed out. A French form which was widely tried a few years ago had a pair of sets, each of six springs, with a long curving shape, one end attached to the hub and the other to the rim, while the leaves on the two sides were set in opposite directions. The idea was that loading would produce an eccentric movement of the rim relative to the hub, and that the opposing of the two sets of leaves would produce an absorption, one side absorbing the tendency to movement of the other. In practice, however, this idea did not work out, as it gave a noisy, hard-riding wheel, with a tendency for the springs to break. These disadvantages, added to its weight, put a stop to its use.

An American device, constructed along somewhat similar lines, but with all springs pointed in one direction, had only a limited use in the home town of the inventor and is not now used.

**Modern Status of Spring Wheel.** The more modern view is not that the solid tire will be eliminated, but that a form of steel-spring or other resilient wheel will be produced which will have all the advan-

tages of wood and, in addition, will so save the solid rubber tires that mileages twice as great will be obtained. In this way, the tire cost will be cut in half, which will be sufficient within the ten-year life of the ordinary commercial car to warrant the purchase of the more expensive wheels.

In the use of spring wheels, as well as of wire wheels for pleasure cars, the tire and rim situations are closely inter-woven. No special form of wheel or rim can be successful which calls for a special tire in addition, because, in case of trouble on the road, in a small town, or anywhere outside of the big cities with large and varied sources of supply, the users would not be able to replace the tire. As will be pointed out later, the present rim-and-felloe situation, which might be described as chaotic, must necessarily continue until the tire situation is cleared up. That done—and it is now in a fair way of being done soon—the rim situation also will be quickly cleared up, and, following, that of the wheel felloes. The natural fitness of the various forms and the unfitness of others to meet popular demand is rapidly clearing the way for the engineers and manufacturers who are attempting this standardization work.

## WHEEL TROUBLES AND REPAIRS

The removal and handling of wheels present probably the biggest problems in connection with them. True, broken wheels give the repair man a good deal to think about, but the quick accurate handling of jobs in which a broken wheel figures depends more upon possessing and knowing how to use certain equipment than anything else; the operations are so simple that they require no particular skill or knowledge.

**Wheel Pullers.** In handling wheels a wheel puller of some form is generally a necessity; wheels are removed so seldom that they are likely to stick, and they get so much water and road dirt that there is good reason for expecting them to stick or to be rusted on. This means the application of force to remove the wheel. For this purpose, a wheel puller is needed, and a number of these have been illustrated and described previously, as gear pullers, steering-wheel pullers, etc. Any one of these devices which is large enough to grasp the spokes of the wheel and pull the latter outward and, at the same time, press firmly against the protruding axle shaft will do the work well.

Sometimes, however, while owning a puller, a wheel breaks down on the road where this is not available, or the repair man is called without being told the trouble, so that he does not bring the puller with him. In such cases, the repair man must improvise some kind of a puller out of what he has on hand. Everyone carries a jack, so it is safe to assume that one of these will be available as well as some form of chain. If a chain of large size is not available, tire chains—particularly extra cross-links—may be fastened together to answer the purpose. If chain is lacking, strong wire, wire cable, or, in a pinch, stout rope can be substituted. Attach the rope, wire, or chain to a pair of opposite spokes of the wheel, Fig. 507, allowing usually about two feet of slack. Draw the chain out as tightly as possible, place the jack with its base against the end of the axle and work the head out by means of the lever until it comes against the chain. Then by continued but careful working of the jack, the wheel is pulled off the axle.

Fig. 507. Makeshift Wheel Puller for Road Repair Work

If rope, wire, or wire cable is used, it is advisable to place a heavy piece of cloth, burlap, or something similar over the head of the jack to prevent its edges cutting through this material. With rope only enough slack must be used to allow the jack in its lowest position to be forced under it; this must be done because there is so much stretch to the rope itself and so little movement in

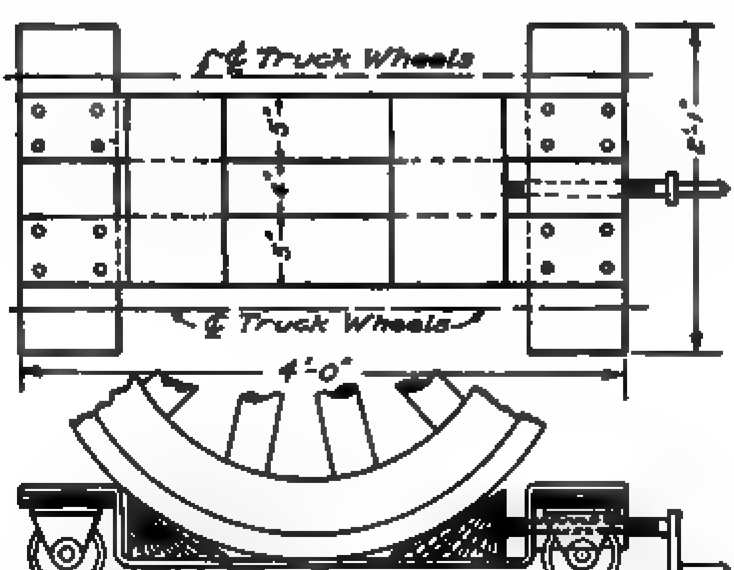


Fig. 508. Tire Platform or "Dolly" for Handling Truck Wheels

the ordinary jack, that the combination of rope and jack does not always work to advantage.

Similarly, the handling of heavy truck wheels gives much trouble even in the garage, for they are so big, heavy, and bulky that ordinarily two men are needed. One man can do the trick, however, with a platform or "dolly" like that shown in Fig. 508. This consists of a platform about 4 feet long by 25 inches wide, fitted with casters at the four corners. Inside of the central part are placed a pair of wedges, one of which can be moved in or out by means of a crank handle. To use this, the wheel is jacked up a little over 2 inches, and the truck pushed under. Then the movable wedge is forced in against the tire so that the two wedges hold the wheel firmly and carry all of its weight. Then the casters are turned at right angles so that the platform and the wheel may be moved off together. The truck wheel is removed in the usual manner, that is, with the aid of the wheel puller or such other means as the garage equipment affords. The dolly also forms a convenient means of handling the wheel when it is put back on its axle.

## TIRES

**Kinds of Tires.** Broadly, there are three general classes of tires: the solid, the pneumatic, and the combination or cushion. The solid tire needs little comment or discussion here—being solely for commercial cars—except in so far as it is used with some form of spring wheel, hub, or rim, as just described. Similarly, the cushion tire is mostly used for electric cars, its use following that of the solid tire.

### PNEUMATIC TIRES

The pneumatic tire was originally developed for bicycle use and in the beginning many single-tube tires were used. All of the tires used today have two parts—an inner and an outer tube.

**Classification.** Considering only the double-tube types, therefore, the pneumatic tire may be divided into three kinds: the Dunlop; the clincher; and various later forms brought out to go with the detachable demountable rims; and similar devices. These latter vary widely in themselves, but all are modifications of the clincher form, with minor differences of the difference in rims.

*Dunlop.* The Dunlop tire, so named after the Irish physician who invented and constructed the first pneumatic tire, is brought

down to meet the rim in two straight portions, perfectly plain and of even thickness, that is to say, the tire has no bead, as it is now called. The tire fabric is brought down to a straight edge at the rim, as well as the rubber covering, as shown in Fig. 509. *A* is the steel rim of the wheel, *B* the inner tube, *C* the outer shoe, which at the rim or inner portion is brought down to the two straight parts *DD*.

This tire, like all of the early tires, had to be put on over the edge of the rim by sheer strength, coupled with the flexibility of the tire when not inflated. This was a hard task, and, moreover, as soon as the tire was punctured or otherwise deflated, there was a strong possibility of its being thrown off, and possibly lost, at east after it had been stretched on and off the rim a few times.

Fig. 509 Section of Dunlop Tire

Fig. 510. Section of Typical Clincher Tire

*Clincher.* To prevent this latter happening, the clincher rim and tire were brought out, each being dependent upon the other. In the clincher tire, the fabric is brought down to the rim, and then, instead of being left straight out as in the Dunlop, the material is formed into a hump, or bead, which is shaped just like the hollow formed in the rim. The latter differs from the usual Dunlop rim only in having this deep depression to fit the bead of the tire. Fig. 510 shows this, in which the parts are lettered as before. In both cases, the fabric of the tire is sketched in, and it may be noted that the layers are fewer in number in the older form.

The great majority of tires now in use are of this type, although, like the original Dunlop, it must be forced on and off the rim by the stretch of the deflated tire, and by sheer strength, coupled in this case with considerable natural ingenuity and some tools for lifting

the hard non-stretchable beading over the edge of the rim at one point. This done, the rest is easy. For this purpose many tools have been bought; some good, some bad, and some indifferent. After a fashion, all do the work, but that tool is best which performs the operation most easily, most quickly, and with the least damage to the tire or rim. Fig. 511 shows a useful tool for this purpose.

The wire wheel and demountable rims, both allow quick road changes of damaged tires, leaving the work of tire repair to be done at home in the garage with proper heat, light, tools, and materials. This is rapidly bringing back into use the lower price clincher and straight-side tire forms, also many new tools have made their removal or attachment a much easier and more simple task.

*Demountable Rim Types.* Following the development of the clincher tire and rim until this form of tire was practically universal, came the first forms of the demountable rims, which consisted of a detachable edge or rim portion, like the edge of the clincher rim in section. These were locked in place in various ways in the different forms, but the first demountable rims—they were called detachable rims—were made by cutting the clincher rims into two parts, one of them detachable. This allowed of slipping the tire on over the rim in a sidewise direction, and did away with the stretching and pulling necessary with the plain clincher. Since this was a tire which was detachable more quickly than the ordinary tire, it was given the name "Quick Detachable", and now both parts are known to the trade as the Q.D. tire and rim.

Fig. 511. Tire Removing Tool

*Non-Skid Treads.* All of the later developments in the clincher tire have been along the line of studded or formed treads to prevent skidding. In this many different things have been tried. Fig. 512 shows sections of many of the representative tires on the market. They are well known, and only the last three need any comment.

Fig. 512 *H* shows the Kempshall (English) tire tread, which is built up of a series of circular button-shaped depressions, or cups,

which hold the pavement by means of the suction set up when they are firmly rolled down upon it. This tire has been very successful in England, but as yet has not been used much in this country.

The Dayton Airless tire, shown in Fig. 512 *I*, is a bridge-constructed cushion tire in which the usual air space is given over to a series of stiffening radial pieces of solid rubber, these with the tread forming the bridge or truss. Fig. 512 *J* shows the Woodworth adjustable tread for converting the usual smooth-tread tires of whatever shape or form into non-skids. It is a leather and canvas

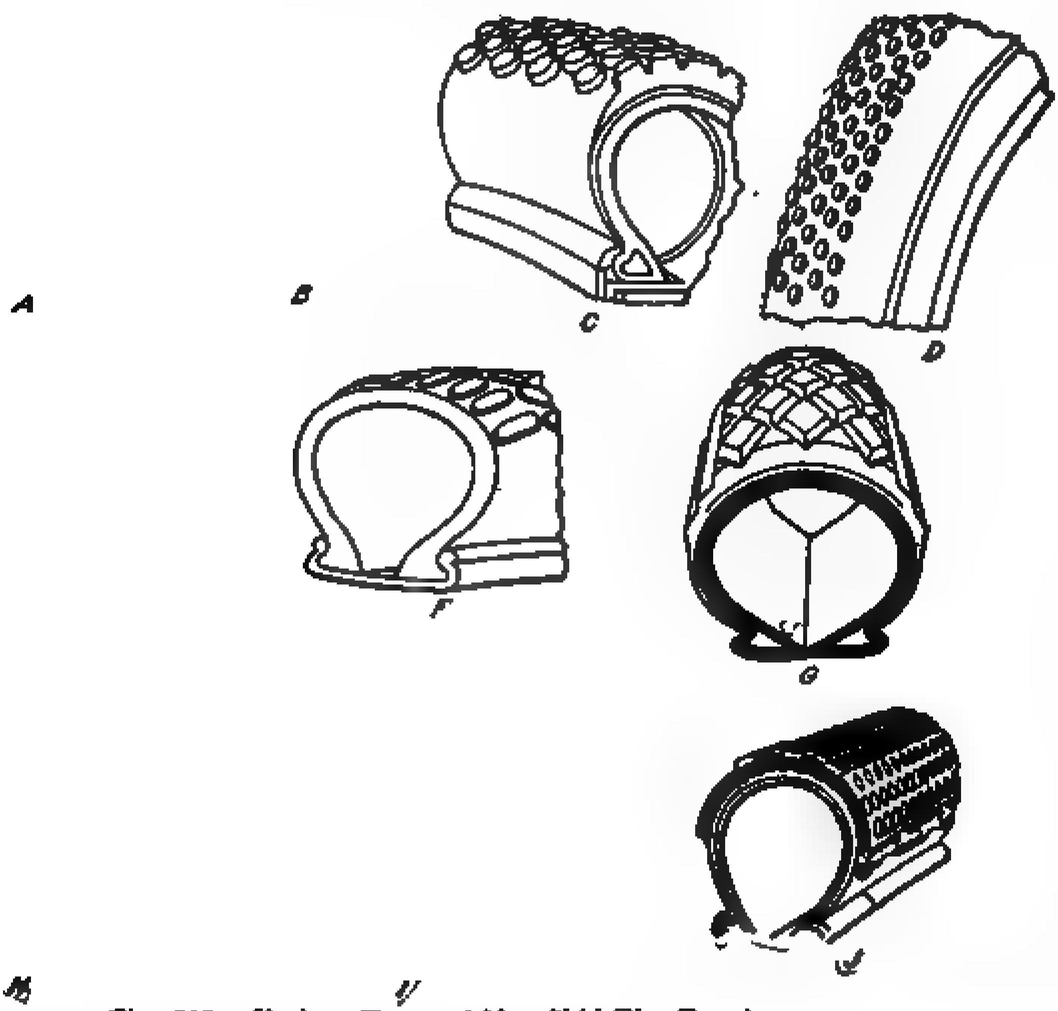



**Fig. 512. Various Types of Non-Skid Tire Treads**

built-up structure, shaped like the exterior of a tire, and freely studded with steel rivets. When in place, the tire has all of the appearance of a leather-tread tire with steel studs.

**Proper Tire Inflation Pressures.** With the recent great increase in the value of rubber and the price of tires, the advice of manufacturers on the subject of tire wear is of great and growing importance. Nearly every manufacturer of tires is now recommending a table of inflation pressures which agree among themselves more or less closely. In each and every case, however, the makers are

advising higher pressures than those generally used, stating that the people do not pump their tires up hard enough to get the best results from the materials in the tires. There should really be no conflict of interests here as the owner should be as anxious to get his mileage out of the tires as the makers are to make good their guarantees.

Many makers have stated, as a result of their years of experience, that more tires wholly or partially fail or wear out from under-inflation than from any other one cause. It thus behooves the owner of a car to look well to the pressure in his tires, not occasionally but very frequently. As the majority of gages attached to pumps in public garages are seriously in error, each motorist is advised to purchase his own gage—one of the pocket type which is simple and inexpensive—and carry it with him at all times.

In some cases, it will be found that pumping the tires up to the makers' specified pressure will result in unusually hard riding, and the motorist must be his own judge as to whether he wants to ride more comfortably and get less wear out of his tires or to put up with the discomfort and get every cent of wear out of them. In this matter, very few will choose the latter course.

*Use of Standard Pressure and Oversize Tires.* There is really a different way out. If the tire pressure advised by the maker results in too hard riding for comfort while comfortable pressures result in too much wear, the motorist is advised to get large size tires. These on the same car will have a greater carrying capacity than the weight of the car by a large margin. Just in the proportion of the tire capacity to the weight of the car will be the pressure recommended to the pressure utilized.

A simple example will make this clear: Suppose, for instance, a car weighing 3850 pounds, equipped with 34- by 4-inch tires, for which the makers claim a carrying capacity of 1100 pounds per wheel and recommend a pressure of 95 pounds. If this pressure be too high for comfort, and lower pressures, say 80 or 85 pounds, result in too rapid wear, the motorist should use larger tires. For instance, a 34- by 4½-inch tire is scheduled to carry 1300 pounds per tire, and the pressure recommended is 100 pounds. The car weight per tire is 962 pounds, say 970. Changing to the larger tire gives a capacity of 1300 pounds per wheel, while the load is actually but 970. This

change provides a surplus capacity which can be utilized to increase comfort.

Hence, if the tire be pumped up in the ratio of the carrying capacity of the tires to the actual weight carried, the spirit of the manufacturers' instructions will have been followed, comfort assured, and long life of the tire attained as well. Here the ratio of the capacity to the weight is as 1300 : 970. If now the pressure be figured from this, using the 100 pounds recommended, a suitable pressure will be obtained. Thus

$$1300 : 970 : : 100 : x$$
$$x = 74.6 \text{ pounds}$$

The pressure, therefore, in round numbers will be 75 pounds, and if this or any comfortable pressure above this be used, only the proper amount of tire wear will result, and a comfortable riding car will be assured.

However, this proposition, namely, changing from 34- by 4-inch to 34- by 4½-inch tires, is one which calls for entirely new rims, and possibly entirely new wheels, or at least new felloes, because the bottom diameter of the 34- by 4½-inch is different from that of the 34- by 4-inch. In such a case as this, the motorist would gain by changing to a still larger size, say 35- by 4½-inch, which change can be made without disturbing the old rims, as the 35- by 4½-inch is an oversize for 34- by 4-inch. This size also is recommended to carry 1300 pounds at 100 pounds pressure per square inch, but maximum pleasure and comfort will be obtained from it at between 72 and 80 pounds.

In general, the rule for oversize tires is this: Oversize tires are 1 inch larger in exterior diameter and ½ inch greater in cross-section than the regular sizes, and any tire so sized will fit interchangeably with the regular size on the same rim. In general, too, the even-inch sizes, as 30, 32, 34, etc., are considered as the regular sizes, while the odd-inch sizes, as 31, 33, 35, etc., are considered as oversizes. The above is for American or inch sizes only. The foreign, or millimeter, tire and rim situation is in an even worse condition, and changes of sizes are difficult in all cases and impossible in most.

**Changing Tires.** In the matter of changing tires, care must be exercised in selecting the new tire of such a size as will fit the old rim. A larger section of tire of the same nominal outside, or wheel, diameter would call for a smaller rim diameter, meaning a change in

rims and possibly wheels. A larger nominal outside diameter will change the speed of the car and, if great, may be too much for the engine, calling for new gearing as well. The following tabular matter will be of interest, as it gives the changes in the metric size tires which can be made without altering either wheel or rim or changing the gearing.

**Possible Tire Changes**

| | |
|---|---|
| 760 mm. × 90 mm. wheels can be altered to..... | 765 mm. × 105 mm. |
| 810 mm. × 90 mm. wheels can be altered to..... | 815 mm. × 105 mm. |
| | and 820 mm. × 120 mm. |
| 840 mm. × 90 mm. wheels can be altered to..... | 850 mm. × 120 mm. |
| 870 mm. × 90 mm. wheels can be altered to..... | 875 mm. × 105 mm. |
| | or 880 mm. × 120 mm. |
| 910 mm. × 90 mm. wheels can be altered to..... | 915 mm. × 105 mm. |
| | or 920 mm. × 120 mm. |
| 815 mm. × 105 mm. wheels can be altered to..... | 820 mm. × 120 mm. |
| 875 mm. × 105 mm. wheels can be altered to..... | 880 mm. × 120 mm. |
| | or 895 mm. × 135 mm. |
| 915 mm. × 105 mm. wheels can be altered to..... | 920 mm. × 120 mm. |
| | or 935 mm. × 135 mm. |
| 880 mm. × 120 mm. wheels can be altered to..... | 895 mm. × 135 mm. |
| 920 mm. × 120 mm. wheels can be altered to..... | 935 mm. × 135 mm. |

These can be used without changing the gearing or the wheels, but to use different tires without changing rims is another matter. It will, therefore, be necessary to have another table of the various tires which are interchangeable on the same rim. Of the makes which are fairly international in character may be mentioned the German "Michelin" and the French "Continental". The following Michelin tires may be fitted to the same rim, the two tires on the same horizontal line being interchangeable in each case:

**Interchangeable Michelin Tires**

| | | |
|---|---|---|
| 650 mm. × 65 mm. | and | 700 mm. × 75 mm. |
| 700 mm. × 65 mm. | and | 750 mm. × 75 mm. |
| 750 mm. × 65 mm. | and | 800 mm. × 75 mm. |
| 800 mm. × 65 mm. | and | 850 mm. × 75 mm. |
| 700 mm. × 85 mm. | and | 710 mm. × 90 mm. |
| 750 mm. × 85 mm. | and | 760 mm. × 90 mm. |
| 800 mm. × 85 mm. | and | 810 mm. × 90 mm. |
| 860 mm. × 85 mm. | and | 870 mm. × 90 mm. |

The following tires of the Continental make are interchangeable on the same rims:

**Interchangeable Continental Tires**

750 × 75 (motor cycle) and 750 × 80 (voiturette)
750 × 65 (motor cycle) and 750 × 65 (voiturette)
800 × 75 (motor cycle) and 800 × 75 (voiturette)
700 × 85 and 710 × 90 (light and heavy)
750 × 85 and 750 × 90 (light and heavy)
760 × 90 and 700 × 100 (light and heavy)
870 × 90 and 810 × 100 (light and heavy)
910 × 90 and 910 × 100
820 × 100 and 820 × 125
880 × 120 and 880 × 125
920 × 120 and 920 × 125
815 × 105 fit only 105 mm. rims

NOTE. Although the 105 mm. tire requires a special rim, a 90 or 100 mm cover can also be fitted on the same rim in the case of necessity.

810 × 90 or 810 × 100 fit on the 105 mm. rim
875 × 105 fit on the 105 mm. rim
910 × 90 or 910 × 100 fit on the 100 mm. rim
895 × 135, 935 × 135, and 1000 × 150 require their own special rims

*Speed Changes Due to Changed Tires.* Before leaving the subject it might be well to say a few words concerning the change of speed which a change in tire sizes will make in a vehicle, this in some cases being so serious as to impair the utility of an engine formerly found to be right in every particular. In the course of a very wide experience, the writer has found this to be the case with many old cars. Using the old small wheels and tires, the engine was able to negotiate all grades easily and make the required speed at all times. With a change to larger wheels and tires, the car ran faster at all times and gave much more trouble generally. It also proved a poor hill climber, so much so, in fact, that the owner had to go one step further and change the gearing so as to give the old speed ratios before the engine again acted satisfactorily.

**Recent Tire Improvements.** There have been but three recent notable improvements in tires which are briefly discussed.

*Tire Valves.* There have been several kinds of troubles with the old form of tire valve. It was spring actuated, and the springs were so small as to cause much trouble; further, it had to be screwed in place, requiring a special tool. There are several new valve forms with more than one seat, and others with an improved seat designed to screw in with the fingers and to offer little or no resistance to inflation.

*Inner Tubes.* Improvement has been made in inner tubes y the use of better and purer rubber in much thicker sections. ome of these have a partial fabric reinforcement; others are made nd then turned inside out so that the tread portion is under com-ression, thus resisting punctures or internal pressure. Other lesigns present a tube larger than the inside of the tire before infla-ion; this produces a truss formation of the rubber, which the air ressure stiffens.

*Cord Tires.* The real improvement of value, however, is the ord tire. One form of this is shown in partial section in Fig. 513. This shows graphically that the difference between this tire and

Fig. 513. Section of Goodrich Silvertown Cord Tire, Showing Inner Construction

other forms is that the 4 to 6 or more layers of fabric have been replaced by two layers of diagonally woven cord. This cord is continuous, rubber impregnated, rubber covered, and, through its size, allows a great and very even tension. Lessening the amount and thickness of the fabric has given a greater percentage of rubber in the tire; consequently, the cord tire is more resilient. The advantages claimed for it are: less power used in tire friction, which means more power available for speed and hill climbing; greater carrying capacity in same size; saving of fuel; greater mileage per gallon of fuel; additional speed; quicker starting; easier steering, thus less driving fatigue; greater coasting ability; increased strength; and practical immunity from stone bruises owing to superior resiliency.

## RIMS

**Kinds of Rims.** Nearly all rims are of steel or iron, but vary greatly as to types. The writer has therefore chosen only a few of the well-known ones, no preference being shown in this.

Rims will be taken up in the order of their development. Naturally, the first rims were of the plain type, while the latest are of the demountable, remountable, or removable types, all these being very much the same. Between the two came the clincher rim, which is properly a plain rim; and the quick-detachable rim.

**Plain Rims.** The form of rim first used was naturally the solid type, shown with the Dunlop tire in Fig. 509. This form is a simple endless band with two edges just high enough to prevent the tire from coming off sidewise when it has once been stretched in place. Nothing like it is used today, the nearest approach being the form of rim used with single-tube bicycle tires.

**Clincher Rims.** Clincher rims were brought out primarily to avoid the weaknesses of the Dunlop, viz, a weakness at the base, and, hence, it had an unusually heavy bead. Another fault which this tire remedied was the tendency under high pressure for the tire to draw away from the rim. This was avoided by the edge of the clincher being made fairly wide where it was designed to go into the pocket, or groove, formed by the contour of the rim.

It is the depth of this pocket, or groove, and the corresponding size of the edge of the bead on the tire, both excellent qualities, which make the tire hard to put on and take off. This may be seen from the previous illustrations of clincher tires, notably Fig. 510.

**Quick-Detachable Tire Rims.** It was this inherent difficulty of handling the clincher tire and rim which brought about the quick-detachable tire. This did not differ from the clincher tire in the tire portion, the difference being in the rim, which has one curved portion made in removable form, with a locking ring outside of it or made integral with it. In some quick detachables, the rim is expanded by a special tool and a spacing piece set into place, which holds the edge expanded. When this is done, the ring—as it is a simple ring with special ends—is held in place until released by the use of the special tool. On the end of the ring there are two little square lugs which project downward and have a hook shape. The one edge of the rim, made flat and straight on that side, has a slot with stag-

gered, rectangular ends into which these lugs fit. It requires force o spring the rings together so the lugs will go into the slots, but once n place, the natural springiness of the rings holds them firmly in place, and holds the tire as well.

Figs. 514, 515, and 516 are given to show how this ring is put in place on a tire. Fig. 514 shows the beginning of the operation, and the instructions for the different steps will make them clear. Thus:

Always start with left end of the ring. Lock this in the rim as shown in Fig. 514, so that the end of the ring is flush with the slot provided for the second end. A dowel pin is provided to register the ring in the proper place. This must always be correctly centered or the ring cannot be applied. This done, the balance of the ring can be forced over the flange of the rim, as shown in Fig. 515, with the exception of the locking end. By means of the tool, the last locking end can be

Fig. 514. Putting on a Q.D. Tire The Start

Fig. 515. Putting on a Q.D. Tire. Forcing Flange over Rim

raised and forced over the rim into the recess provided for holding the same in position preparatory to drawing the ends together, Fig. 516, showing the correct position of the tool.

Then by entering the two points of the tool in the holes provided in the ring, the ends may be drawn together, as shown in Fig. 516, and, with a slight additional leverage, the ends of the rings can be made flush.

Before proceeding further, it should be stated that the object of the quick-detachable rim is the quick removal of the tire, in order to allow a quick repair or substitution of the inner tube. On the other hand, the object of the demountable, remountable, removable, and other rims is the removal with the tire of the rim itself to allow

the substitution of a new tire and rim, the tire being already inflated and ready for use as soon as applied. The object of the removable wheel is the removal of the entire wheel with rim and tire in order to substitute a spare wheel with already inflated tire.

It might be thought that these methods called for the carrying of extra weight, but the amount added is actually very small, as, by their use, tire tools and pump are dispensed with and their weight saved.

Fig. 516. Putting on a Q.D. Tire. The Locking Ring

Fig. 517 shows the former Goodyear rim. This rim, as will be noted, is of the quick-detachable type, the idea being to remove the tire only. The rim itself has a button-hook shape with a slight ridge, or projection, answering to the handle. This is on the fixed side, the inner flange inside of the tire butting against it as a stop. The tire is pushed over against this, being held on the outside by a second flange of similar shape. The latter, in turn, is fixed in place by a locking ring, a simple split circular ring of deep oval section. This fits into the button-hook portion, its contour being such as to fit it exactly. In use, it is sprung into place, the outer edge of the hook on the rim and the natural spring of the ring preventing it from coming out. This makes a very simple and serviceable quick-detachable rim. To make doubly certain that the locking ring cannot jump out, a spreader plate is attached to the valve stem; screwing this down into place wedges the bead of the tire over against the outer flange,

Fig. 517. Former Goodyear Universal Rim

which, in turn, pushes the locking ring tight against the outer curved part of the hooked rim. When in this locked position, the upper part of the flange hangs over the locking ring, so that it cannot rise vertically, the only manner in which it could come off. This rim is shown with a detachable tire in position, but may be used with any standard clincher tire by the use of extra clincher flanges. Fig. 518 shows the rim with a set of these flanges in position, ready to take a standard clincher tire.

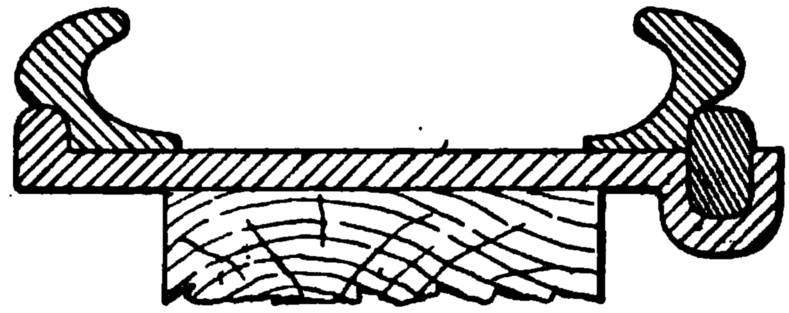


Fig. 518. Adapting Goodyear Rim to Clincher Tires

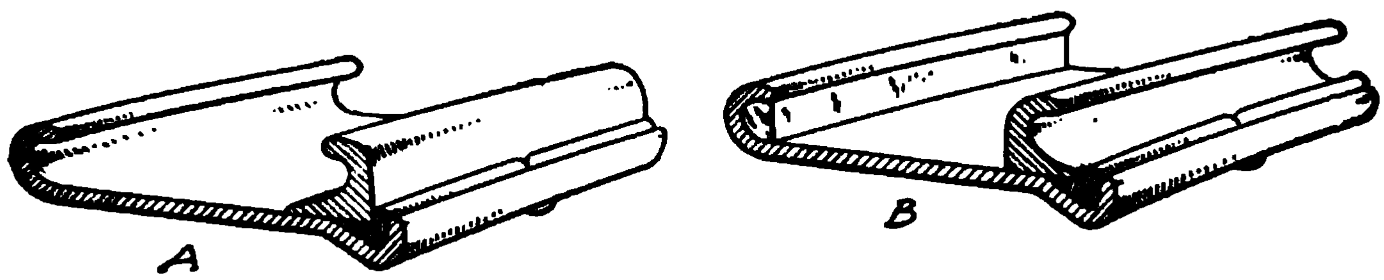



Fig. 519. Universal Q.D. Rim No. 2 Arranged for Clincher and Dunlop Tires

*Quick-Detachable Number 2.* Figs. 519 and 520 show the standard quick-detachable rim, now known as No. 2. This was adopted by the Association of Licensed Automobile Manufacturers

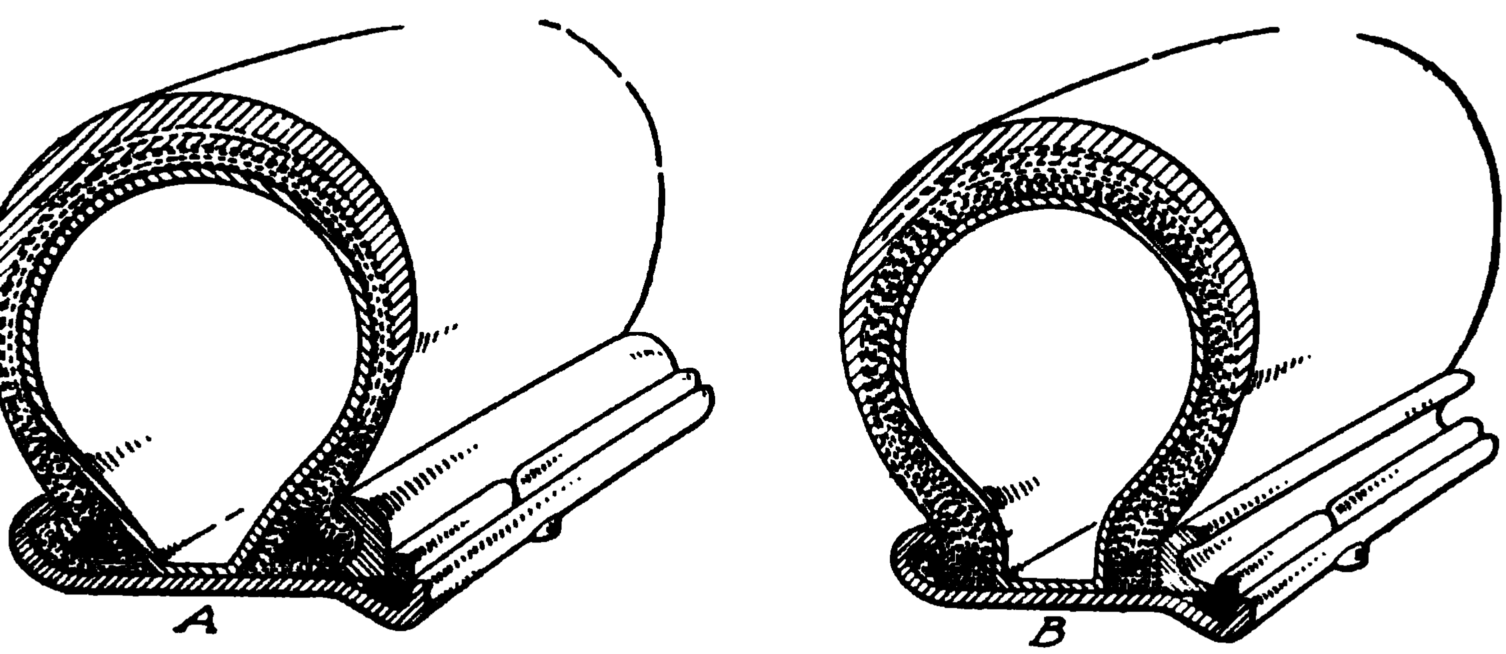



Fig. 520. Universal Q.D. Rim with Tires in Place

as a standard and given the above name. It has the feature of accommodating all regular clincher, or Dunlop tires. In Fig. 519, it is shown at *A* ready for a clincher tire and at *B* ready for a Dunlop tire, the adaptation for the straight sides being shown.

The two parts of Fig. 520 show sections of tires in place, making clear the exact use of this reversible flange. *A* shows a regular clincher tire in place, while *B* reveals the reversed flange in place with a Dunlop tire. Both Figs. 519 and 520 show the construction of

the device, the outer dropped portion of the rim having a hole through it. The locking ring is split vertically and one end, just at the split, carries a projection or dowel pin extending downward. To put the rim on, this dowel pin must be fitted into the hole in the rim to give a starting place. When this has been done, one may force the balance of the ring into place around the wheel with any suitable, thin, wedge-shaped tool.

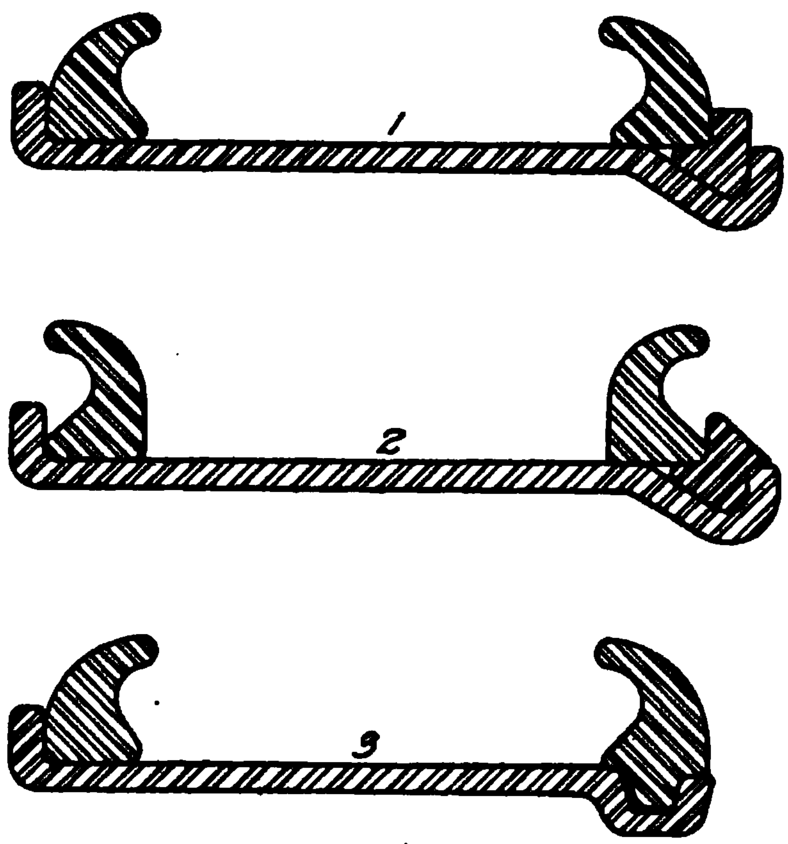


**Fig. 521. Sections through Three Popular Q.D. Universal Rims**

The shape of this locking ring with a right-angled groove in its inner edge permits the outer flange to overlap it, which insures the retention of the ring when once it has been put in place. Furthermore, it gives the outer side flange a wider seat on the rim, thus making it more stable and longer wearing.

As will be noted, the difference between these two rims—that is, the old Goodyear and the Universal No. 2—lies in the saving of one ring and the shape of the locking ring. Both of these are called universal rims because they may be used interchangeably for straight-

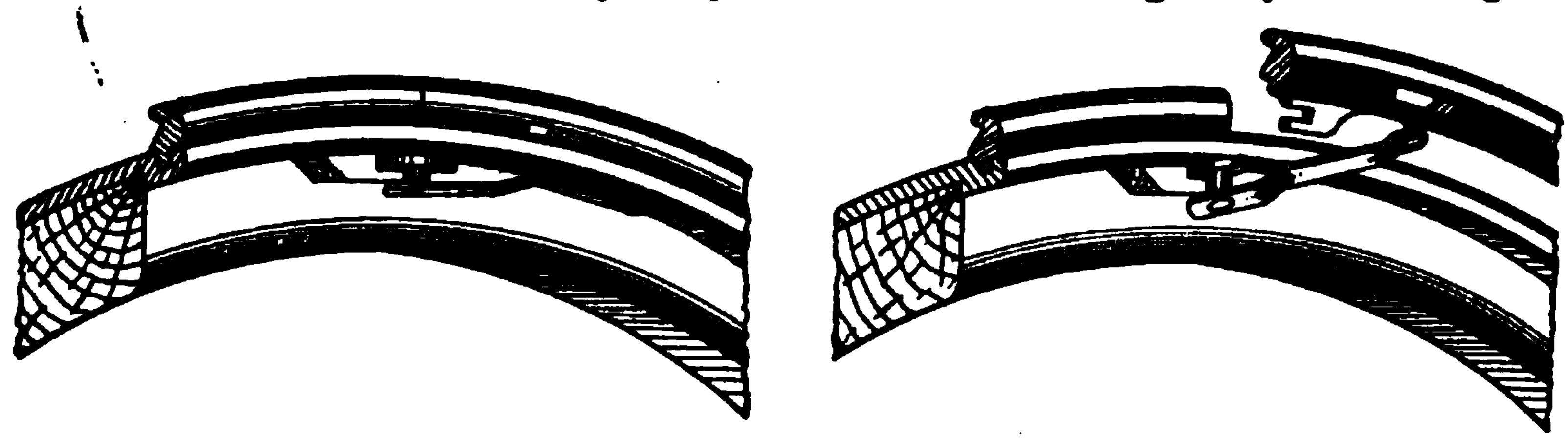


**Fig. 522. Latch Used for Locking Single Combination Ring which Replaces Former Side Ring and Locking Ring**

side and clincher types of tire. Other Q. D. Universals are shown in Fig. 521, although, in the opinion of tire men, the Universal form is slowly going out of use.

To explain these briefly, No. 1 is a modification of the Goodyear, with different shaped inner rings, while the locking ring and the lip formed in the felloe band to receive it are similar to those of Universal No. 2. In *2* the only difference from *1* lies in the locking ring,

which has a modified Z-section, with a lip extending over the outer edge of the felloe band. The third section differs from the other two only in having the outer ring and locking ring combined into one, and the felloe band changed to suit this. This combination ring is held in place by means of a simple swinging latch, which is shown open and closed in Fig. 522. When opened, this permits raising the end of the ring, to which the shape of the felloe band offers no resistance. The whole inner ring is taken off, following around the circumference of the wheel, after which the tire is easily removed.

*Quick-Detachable Clincher Forms.* To return to the plain clincher tire and the Q. D. rim, which allows of its ready removal,

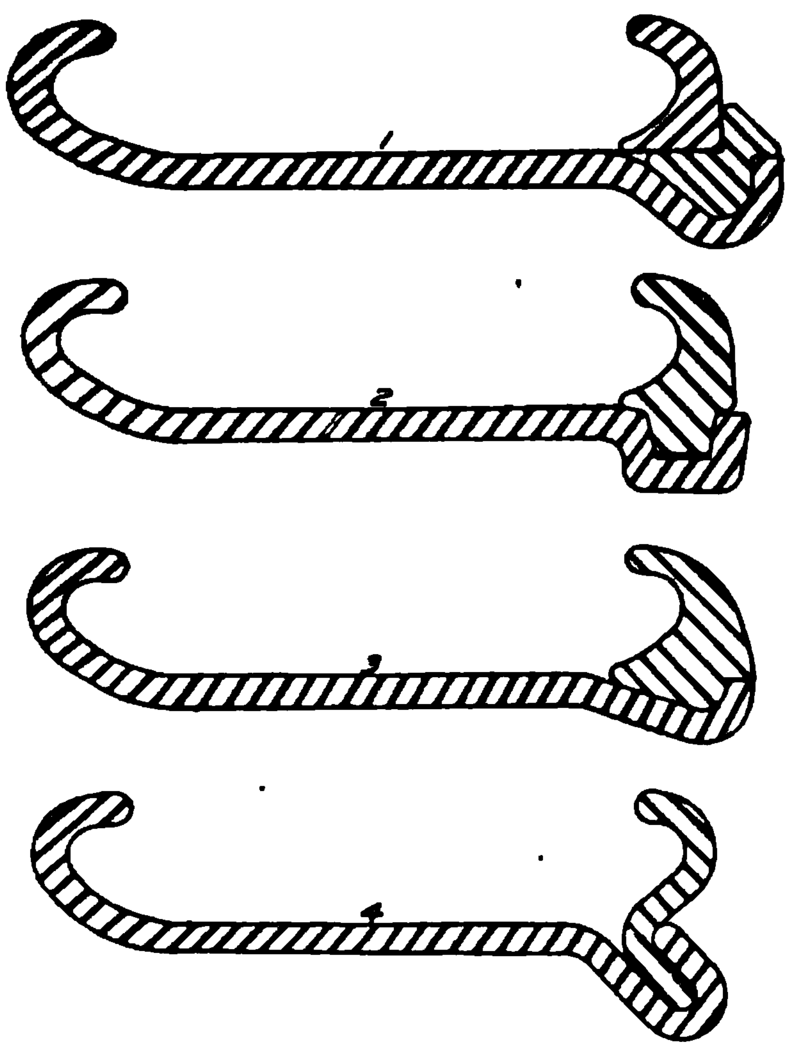



Fig. 523. Popular Forms of Q.D. Clincher Rims, Shown in Sections

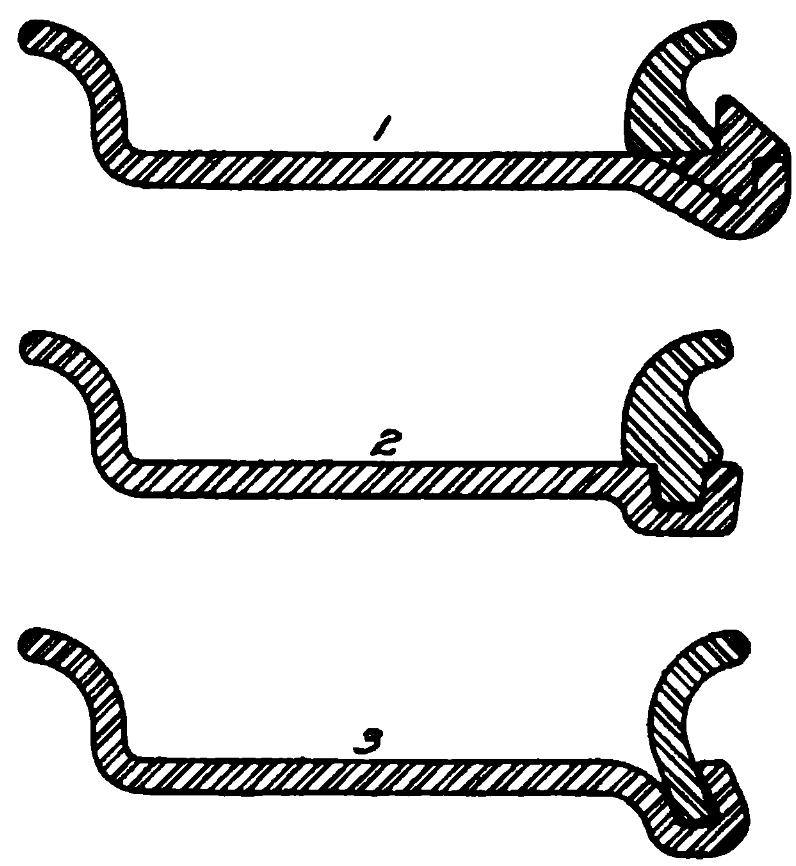



Fig. 524. Three of the Most Widely Used Straight Side Q.D. Rims

Fig. 523 shows four of the most prominent forms, these being indicated simply as flat sections of the rim, for the tire is the same in all cases. All these have the simple clincher edge on one side, with removable ring and locking device on the other. That at *1* has the same locking device shown at *2* in Fig. 521, the Z-shaped ring extending over the edge of the band. That at *2* is practically the same as *3* in Fig. 521. The one seen at *3* is similar to that at *2* except for the detailed shape of the ring as well as the lock (not shown). The advantage of the form shown at *4* is that the outer ring is self-locking, that is, the shape of ring and band are such that when the former

is in place the tire itself locks it. Its only disadvantage is that it is harder to operate than the other forms, yet despite this fact it has been recommended for general adoption as the only Q.D. clincher rim worth continuing.

*Q.D. Type for Straight Sides.* To close the subject of straight side tires, the rims of the quick-detachable form now in use aside from those already shown are seen in Fig. 524. Here these are seen to be identical with *1*, *2*, and *4* of Fig. 523, except that the fixed side is arranged for a straight side instead of being made with a clinch. Here again, the last form of self-locking type has been recommended as a standard.

**Demountable Rims.** All, or practically all, demountable rims come under one of two headings—those in which the tire can be detached on the wheel without demounting (if it is so desired) and

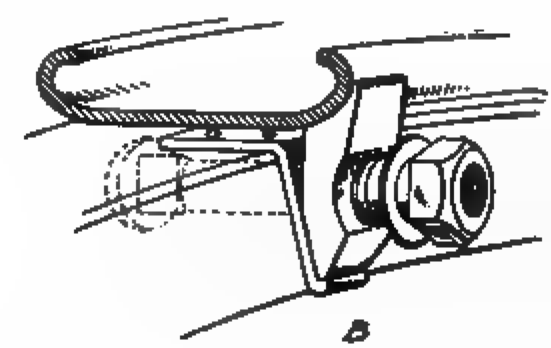



Fig. 525. Sections of Michelin and Empire Demountable Rims

those which are of the transversely split type and must be demounted before the tire can be removed. In addition, there is a second division of demountable rims into those which have a local-wedge form of attachment and those which have a continuous holding ring, this, in turn, being held by means of local wedges. Any of the plain demountables, which will be called demountables from now on, may be of either type of attachment, as is also the case with the first-named or demountable detachables.

*Local Wedge Type.* In the so-called local wedge type, which includes the well-known Continental forms (notably Standard Universal Demountable No. 3 and Stanweld No. 22 and No. 30), Michelin, Empire, Baker, Detroit, Prudden, Standard Universal Demountables No. 1 (formerly the Marsh), and No. 2, and others, loosening the six (or eight, as the case may be) bolts frees the rim directly without further work. In some of these, such as the Michelin; the various Continentals, including Stanweld No. 22 and No. 30;

Detroit; Baker; and others, the wedges carry a projecting lip, which makes it necessary to unscrew the nuts far enough to allow the removal of the wedge so as to pick this lip out from under the tire-carrying rim. In others, such as Empire, S.U. No. 1 and No. 2, the construction of the wedge and rim is such that loosening them frees the rim, the upper part of the wedge or clip swinging down to the bottom position as soon as loosened, because of its heavier weight and the fact that there is no projecting edge to prevent it. While this latter construction makes a faster operating rim, it is an open question as to whether it is as safe as the other form. These two constructions are shown very plainly in Fig. 525, in which *A* is the Michelin with lipped wedges, and *B* the Empire with plain wedges.

Fig. 526. Two Popular Demountable Rim Forms—for Clincher Tires above, for Straight Side below

In Fig. 526 is shown a pair of additional demountables, which are held by the local wedge method, the difference here being in the form of a wedge. Note that *1* has a solid clincher rim and *2* a straight side rim. The base, however, is the same for both and, as will be seen by examining this, has two curves in its upper surface, the straight side rim fitting into the lower

Fig. 527. Sectional Drawing Showing Construction of Baker Demountable Rim

or bottom one, while the clincher form of rim fits into the upper one. Note, also, that the wedges are the same for these two. This makes the demountable parts of the rim practically universal in that the owner can change from clincher to straight side or *vice versa* by simply purchasing the extra set of tire-carrying rims, no change in the wheels or means of attachment being necessary. For this reason, the felloe band shown under these two rims has been suggested as a standard for demountables.

Fig. 528. The First Operation in Removing Baker Demountable—Loosening the Bolts

*Process of Changing Baker Local Wedge Type.* In Fig. 527 is shown the Baker, which, as mentioned previously, is of the local wedge type of demountable, having a transversely split rim which must be removed from the wheel before the tire can be taken off. Perhaps this whole action will be shown more clearly by the progressive series of views, Figs. 528 to 538, which show the various steps in removing and replacing a tire and tube mounted on a Baker rim, the same as is shown in section in Fig. 526. First, all the wedge bolts except the two nearest the valve stem, one on either side, are loosened by means of the special brace

Fig. 529. Second Baker Demounting Operation—Jacking the Wheel and Starting to Pry off Rim

until the wedges swing out and down, as shown in Fig. 528. As mentioned previously, this means quite a little loosening, for the wedges have a long lip which projects under the tire-carrying rim. When this has been done, and as each one swings down out of the way, it is tightened just enough to prevent the wedges from swinging back.

This done, the wheel is jacked up off the ground, as shown in Fig. 529, and the point of the tire tool is inserted between the felloe band and the rim carrying the tire at the point opposite the valve, where, it will be remembered, the wedges were loosened, and the rim will be almost free. By prying the tire-carrying rim outward and working around it toward the valve and back again, it will finally be loosened to a point where, with the valve at the bottom, the rim and tire can be slipped off without lifting it. The extra tire and rim are now put in place.

Fig. 530. Third Baker Operation—Putting on New Tire and Lowering Wheel

This is shown in Fig. 530, where the reverse of the operations shown in Fig. 529 and just described is followed, that is, the valve stem hole is revolved to the top, the valve stem inserted, the rim pressed into place all around, then the wheel is revolved until

Fig. 531 Fourth Operation—Tightening Bolts on the New Tire and Rim

Fig. 532 Fifth Operation—Starting to Take the Rim out of the Tire—Beginning to Pry Short End

Fig. 533. Sixth Operation—Forcing Down the Short End of Rim

Fig. 534. Seventh Operation—Prying under the Loose End of Rim

Fig. 535. Eighth Operation—Raising the Free End of Rim, Using Both Hands

Fig. 536. Ninth Operation—Inserting Valve Stem and Beads in End of Rim

Fig 537 Tenth Operation—Prying Tire Away from Rim to Let Latter Slip into Place

the valve stem comes to the bottom, so that the two wedges which have not been loosened are nearest the ground. Then the jack is let down and removed, the whole weight of the wheel coming on the bottom point where the wedges are already tight, never having been loosened.

This action is necessary as, with the weight on the other points where wedges are still loose, it would be necessary to work against the car weight. At this point, as Fig. 531 shows, the nuts are loosened, using the special brace until the wedges can be inserted under the rim. This done, the nuts are tightened to hold them there. This tightening is continued until the little studs, or lips, in the rim rest on top of the outside edge of the felloe band, using the tire tool to force them in, if necessary. The new tire carried is supposed to be ready for use, that is, inflated to the proper pressure, so that these four actions complete the work of making a roadside change.

When it is desired to repair the tire which has been removed, it is carried home on its rim just as taken off the car wheel, and the rim is removed from the casing as follows: Rim and tire are laid flat on the garage floor, as shown in Fig. 532, so that the outer end of the diagonal cut in the inside of the rim which is farthest from the valve stem is uppermost. An inside plate will be found on the rim which covers the two rivet heads on either side of the cut, with a central hole for the valve stem. This plate is called the anchor plate and must be removed. To do this, begin at the short end of the rim, which does not have the valve stem—as, in this position, it will be held in the long end—and insert the sharp end of the tire tool or a screwdriver under the bead or between the bead and the rim.

These two actions, as shown in Fig. 533, bring the two short sides of the rim closer together and thus reduce the diameter. When the extreme end has been freed in this way, the operation is repeated some 5 or 6 inches farther around, that is, that much farther away from the slit. This done, a considerable portion of one end will be free. Then turn the rim and tire over so that this free part comes at the top instead of at the bottom and, standing on the part which is still tight, insert the tool between the rim and the entire tire.

This frees the entire end, but, to make sure, the tool must be moved a little farther along so as to free more of it. When enough has been freed to allow grasping it with both hands, as shown in Fig. 535,

the tool is dispensed with and, taking a firm grip on the rim, at the same time standing on the tire at the point where tire and rim still contact, pull upward strongly. When followed all the way around this pulls the rim entirely out of the tire.

Having the casing and tube free, they may now be inspected and repaired. When this is done, or if it is not done, and a new tire or tube or both are used, the worker is ready now to replace the rim. This is practically the reverse of the method just followed out. As shown in Fig. 536, the rim is laid on the floor; then the end which has the valve-stem hole drilled in it is raised, and the valve stem inserted. Next the beads are pulled into the rim, it being necessary to press them together somewhat tightly in order to do this, but, with a little practice, it soon becomes an easy matter. All this is done with the other part of the rim underneath the tire.

The inserted end of the rim is followed around with the thin end of the tire tool, as shown in Fig. 537, the position of the tire above the rim allowing the workman to stand on it and thus use his weight to press the two sides of the tire together and, at the same time, to force them into the rim. This operation is followed right around the inside circumference of the tire, the free, or short, end of the rim being the last part to enter. On account of the shape of the joint or cut in it, this should slip readily into its proper place, but if it does not, the thin end of the tool can be used to pry it into place, or a hammer can be used on the longer side to drive it in.

Fig. 538. Eleventh Operation—Inserting Anchor Plate

The rim being fitted snugly into place all around, the anchor plate is inserted, Fig. 538, to prevent the short end slipping out again, and the tire is ready for inflation. If it is to be carried as a spare tire, the dust cap should be screwed into place over the valve stem, so as to preserve the threads which might be damaged in handling.

*Rim with Straight Split.* This covers the action of practically all the demountables in which the transversely split rim is used, necessitating the removal of the rim and tire from the wheel before the

tire can be taken off the rim. However, not all rims are split on a diagonal as is this one, and Fig. 539 is presented to show this single feature on another rim, which otherwise is somewhat similar. Here the rim is split at right angles, having a plain thin rectangular plate *A* attached to the free end, or that which is removed first, while the other end has a swinging flat tapered plate with a cam-shaped end *B*, the action of which is to expand the rim to its fullest diameter and lock it there. In the top figure, it is locked—that is, the rim is expanded as it would be when in use and just after it had been removed for replacement. When the rim is to be removed from the tire, the latch *B* is swung out of the way, as shown in the lower figure, when the catch *C* which holds the two ends together can be opened by lifting the tire with this portion at the bottom and then dropping it a couple of times. This done—usually this action will be accompanied by the free end spring inside the fixed end—continuation of the removal is an easy matter. The rim shown is the Stanweld No. 20.

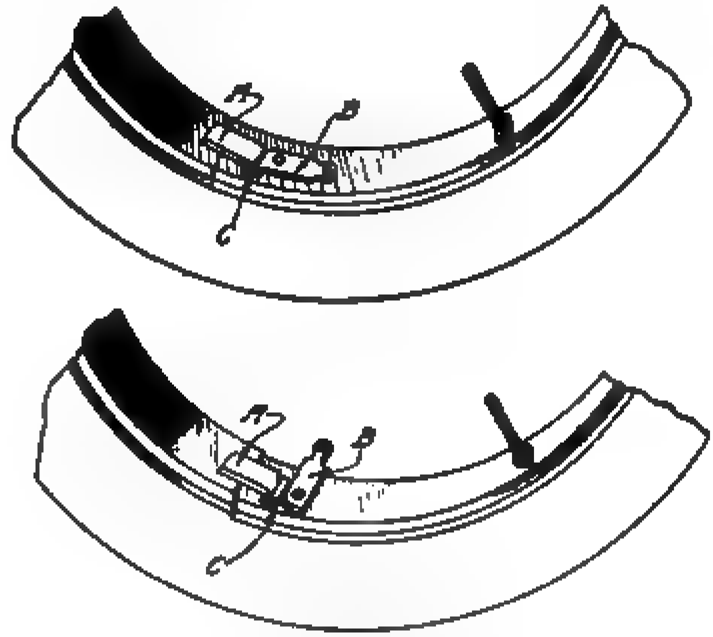


Fig 539. One-Piece Rim, Showing Right-Angled Split and Locking Device
*Courtesy of Standard Welding Company, Cleveland, Ohio*

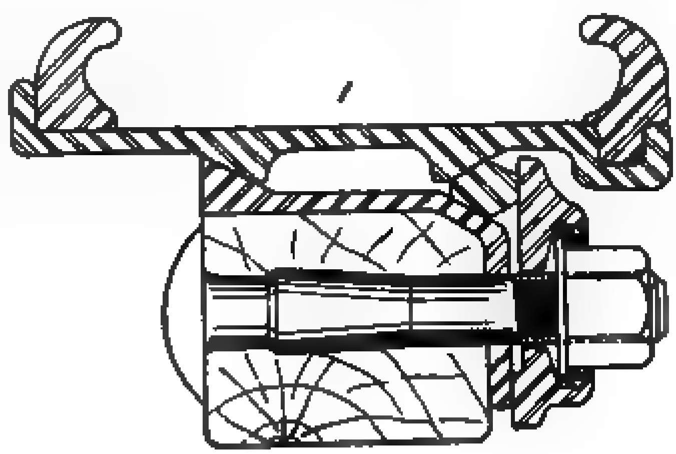


Fig. 540. Sections through Two Popular Forms of Demountable-Detachable Rims

*Comparison of Continuous Holding Ring Type with Local Wedge Type.* To return to demountable-detachable rims, these may and do include a number of those quick-detachable forms previously shown

and described. In Fig. 540, a pair of typical forms is shown, that at *1* being fitted for a clincher tire, while that at *2* is for a straight side. Looking at the detachable part of the rim, *1* will be recognized as that previously shown at *3*, Fig. 521, where it was described as a universal rim, the inversion of the two rings converting it from a clincher to a straight side, or *vice versa*. Similarly, *2* will be recognized as the form of detachable shown at *3* in Fig. 524.

Here, however, both are fitted to be used as demountables, this being accomplished by the formation on the under side of the band of a pair of wedge-shaped projections. The felloe band is so made and applied that it forms one surface to contact with one of these wedges, while the other is formed variously. At *1*, a separate ring is used with the flat outside clips to hold this against both felloe band and rim, while at *2* the wedges or clips have an extension which presses against the outer wedge on the rim. This latter distinction divides these two into the two classes mentioned previously — one into the continuous holding ring class, the other into the local wedge type.

Fig. 541. Section of Tire and Rim of Firestone Demountable Tire

These forms are shown to illustrate this point and also because, despite this difference, they have practically similar felloe bands. This felloe band—that is, of the form shown in *2*—has been recommended as a standard for all demountable-detachable rims. Another and different example of the clamping-ring demountable-detachable type is shown in Fig. 541, this being the Firestone rim. Here, it will be noted, is the felloe band just mentioned, while the detachable-rim portion is that previously shown at *1* in Fig. 523 as having the Z-shaped locking ring and being adapted to clincher tires only. The rim band is made with the two wedge-shaped projections on its underside.

**Perlman Rim Patents.** Late in the summer of 1915, considerable consternation was caused among tire and rim manufacturers when

it became known that the Perlman rim patent had been adjudged basic by the courts, and that, on the strength of this decision, an injunction had been issued against the Standard Welding Company, of Cleveland, Ohio, some few of whose rims have been previously described. Perlman's original patent was applied for on June 29, 1906, and, in addition to this record, the fact was established that the owner had a Welch car which had traveled over 150,000 miles and on which were a set of the original rims. The case dragged through the courts and was discontinued some seven or eight years ago. Perlman persisted, however, although he had to revise and alter his application many times; the basic patents were finally allowed, and issued to him in February, 1913. This means, of course, that the patent will not expire until the year 1930.

Perlman's locking elements and the principle involved are shown in Fig. 542, which is a section through the rim and felloe. In Perlman's suit, it was claimed that the wedge end of the bolt which was covered in his patent, included all wedge-operating rims, whether actuated from the center, as in Fig. 542, or from the side. This contention was supported by the court, and negotiations are now in process between Perlman and many manufacturers of the so-called local wedge type of rim. As this would appear to cover all the rims shown and described in Figs. 525 to 541, inclusive, the influence of this decision upon the industry can be imagined. Moreover, the length of time which this basic patent has to run precludes the possibility of delaying action by prolongation of suits, as has been done in similar cases. A notable example of this is the case of the Selden automobile patents, which were fought on one ground or another over a long period of years.

Fig. 542. Section of Perlman Rim, Showing Locking Device

**Standard Sizes of Tires and Rims.** As might have been noted in going over the above discussion of tires, plain rims, detachable rims, and, finally, demountable rims, all these different constructions require widely differing wheel sizes. It has been proposed to standardize wheels, that is, the outside diameter of the felloe and with

it the thickness of felloe bands as well as their shapes or contours one for each tire cross-section. The proposed reduction of tire size to nine standards is as follows: 30- by 3-inch, 30- by 3½-inch, 32- by 3½-inch, 32- by 4-inch, 34- by 4½-inch, 36- by 4½-inch, 38- by 5½-inch and probably 36- by 5-inch, supplying these sizes and these only to manufacturers of cars; additional oversizes are allowed for car users one for each size above, that is, 31- by 3½-inch for 30- by 3-inch, 31

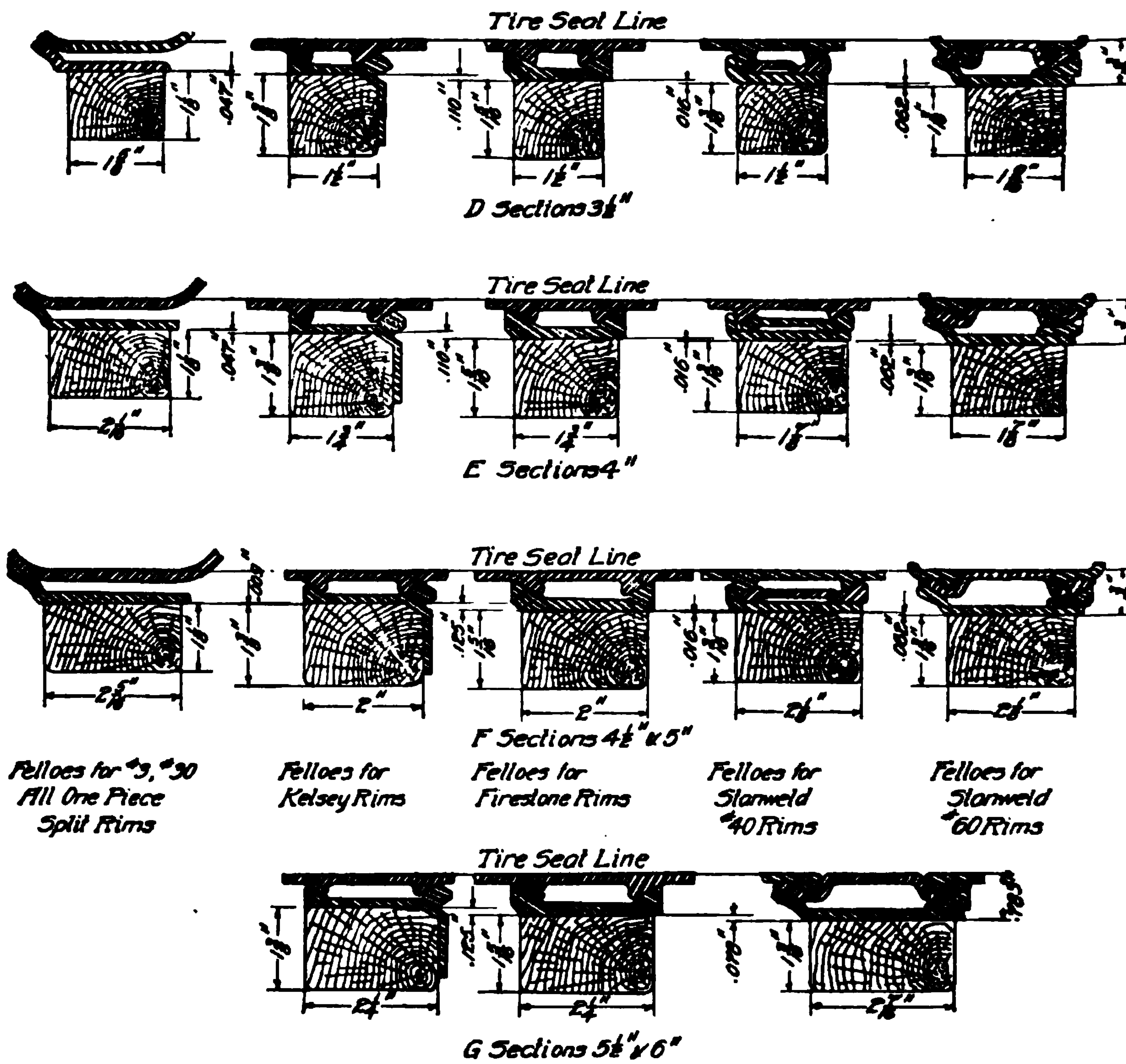



Fig. 543. Typical Felloe, Band, and Rim Sections for Popular Demountable Rims

by 4-inch for 30- by 3½-inch, 33- by 4-inch for 32- by 3½-inch, 33- by 4½-inch for 32- by 4-inch, 35- by 4½-inch for 34- by 4-inch, 35- by 5-inch for 34- by 4½-inch, 37- by 5-inch for 36- by 4½-inch, 39- by 6-inch for 38- by 5½-inch and probably 37- by 5½-inch for the 36- by 5-inch. Rim standardization will follow the adoption of these sizes. In this event, the standardization of demountable rims will come in time.

At the present, there is a wide range of difference, as will be noted in the drawing, Fig. 543, which shows felloes for the most

widely used demountable rims, depicting the band and rim in each case. The drawing should be read crosswise, each horizontal line showing the differences to be found in the makes mentioned in that particular tire cross-section size. Thus, the *D* sections show the differences for 3½-inch tires, *E* those for 4-inch tires, *F* those for 4½- and 5-inch tires, and *G* those for 5½- and 6-inch tires, rims for which are not produced by all makers.

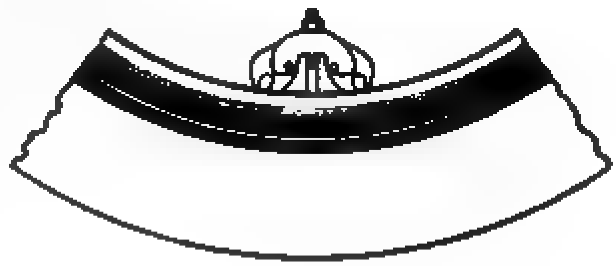


Fig. 544. Operating Device on the Ashley-Moyer Double Q.D. Rim for Wire Wheels

**Other Removable Forms.** Outside of the regular range of wood wheels and the standard tires for them, any different wheel calls for a different treatment. As has already been mentioned under the subject of Wire Wheels, few of these have anything but a solid one-piece clincher rim; first, because the wheel itself is removable, thus making it as easy to change wheels as to change rims in the ordinary case; and second, to save weight and complication.

*Demountable for Wire Wheels.* However, demountable forms have been produced for wire wheels, one being shown in Figs. 544 and 545. This is the G-R-C double Q.D. rim as the makers prefer to call it, in action a demountable-detachable form, the clincher rim being of the straight split type, in fact, a Stanweld No. 20. This is made with a double wedging surface on the

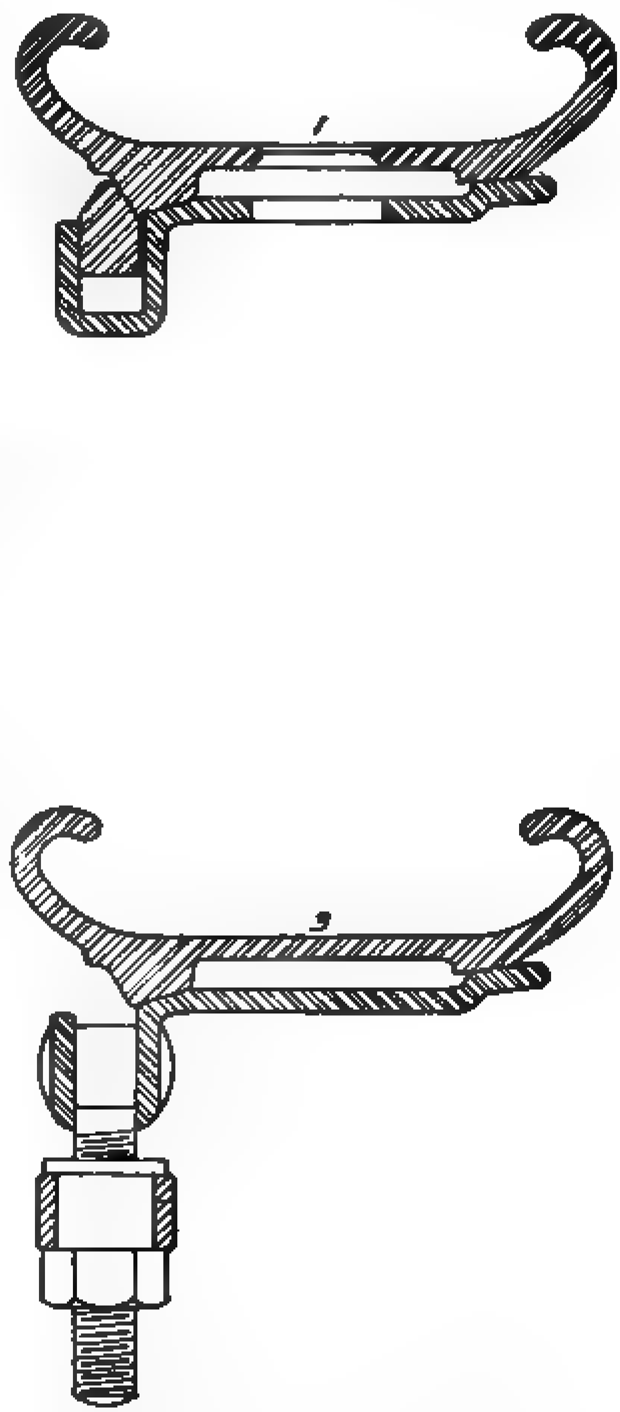


Fig. 545. Section through Rim and Band of G-R-C Rim, Showing Wedging Band and Its Operation

outside and a single one on the inside. The latter contacts with another on the false rim to which the wire spokes are attached, as does also the inner wedging surface on the outer wedge. The outer wedging surface is made so as to come just above a fairly deep slot in the false rim. In this is placed a ring with a double wedge-shaped upper edge and a square lower edge. This ring is split at one point and locked in the highest position at the point diametrically opposite.

At the split point, a pair of bent-arm levers, Fig. 544, are connected to the two ends. Attached to a middle point of each of these is one end of an inverted U-shaped member, the center and upper part of which form a bearing for a locking stud, which is attached to one end of the ring. Above this is placed a nut. As will be noted, this forms a toggle motion, the action of which is to expand the whole ring when the nut is screwed down and to contract it when the nut is screwed up.

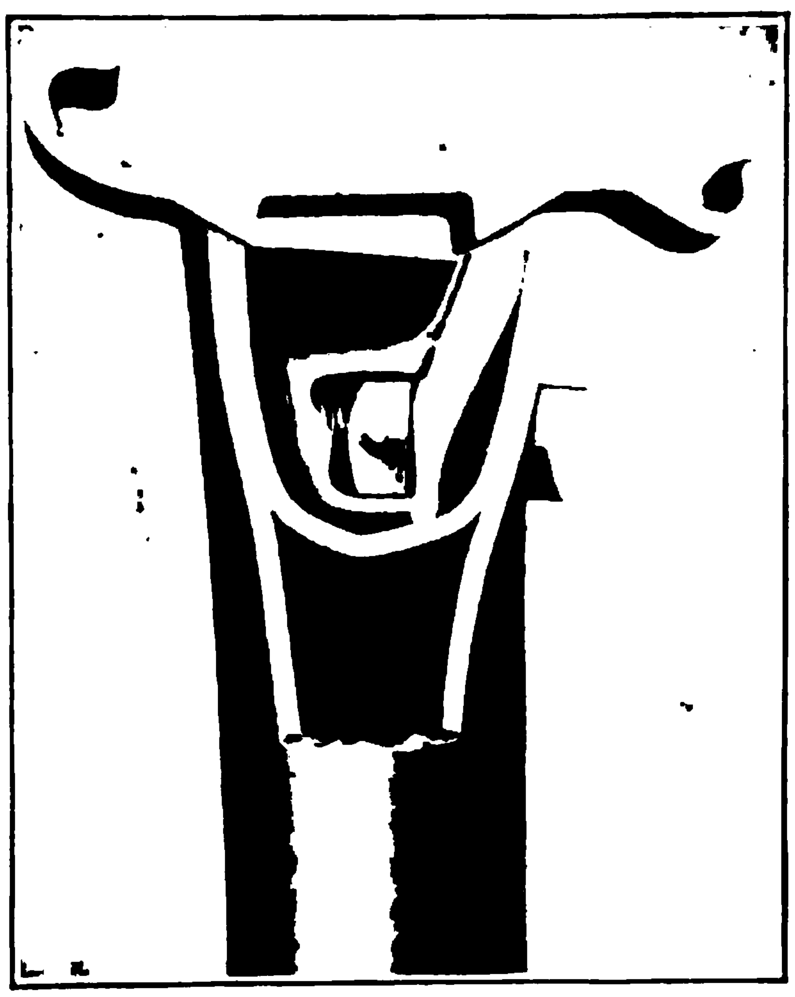


Fig. 546. Construction of Parker Hydraulic Steel Wheel Spokes, and Operation of Locking Device for Rims

This is the precise action used, the single ring forming the whole locking means, and being actuated by the toggle mechanism through the medium of screwing the nut up or down. While at its best on wire wheels because of its simplicity, this rim is, of course, applicable to wood wheels. At present, its makers are specializing on the wire-wheel forms.

*Parker Rim-Locking Device.* Another rim-locking device which does not come under any of the standard divisions, being devised for use on the Parker hydraulic wheel, previously shown in Fig. 502, is the Parker modification of the former Healy rim. As shown in Fig. 546, which shows the end of a steel spoke in section, this is made with a cup at the upper and inner end, while at the outer is a loose clip, through which passes a bolt with a head on the outside. Tightening the bolt by means of the external head draws the clip

up the incline at the bottom of the cup, against the wedge on the underside of the rim, the amount of pressure exerted depending solely upon that applied to the bolt head. As the two wedge shapes oppose each other, this holds the rim as firmly as is possible. It will be noted that this construction does away altogether with the use of felloe bands or false rims used on other forms of rims or wheels, thus saving much weight. Moreover, a great part of the weight is saved at the outside, where the flywheel effect of rapid rotation is thus lessened. Moreover, the absence of additional metal here would give the tire more chance to radiate its heat, and thus would preserve it better. This construction, considering its many advantages, should have a wide use.

Similarly, with all demountable rims, the tendency is toward wider use, with which comes lower cost, as well as a better understanding of their use, abuse, attachment, and detachment. With the standardization of tires to a few standard sizes, say 9 instead of 54, it will be only a few years before all kinds of rims, including demountables, will be standardized, at which time the latter will come into universal use.

## TIRE CONSTRUCTION

**Composition and Manufacture.** Tires consist of two parts, the tube and the shoe, or casing. The former is a plain ring of circular cross-section, made of pure rubber, containing an air valve, and is intended only to hold the air. The shoe, or casing, on the other hand, provides the wearing surface, protects the air container within from all road and other injuries, and constitutes or incorporates the method of fastening itself to the wheel. In its construction are included fabric—preferably cotton—some pure rubber, and much rubber composition, the whole being baked into a complete unit by heat in the presence of sulphur, which acts somewhat as a flux for rubber.

Considering a typical tire, there enters into its make-up, starting from the inside, six or seven strips of frictional fabric, that is, thin sheets of pure gum rubber rolled into intimate contact with each side of the cotton, making it really a rubber-coated material. Next, there is the so-called padding, which is more or less pure rubber, has a maximum thickness at the center of the tread, and tapers off to nothing at the sides, but usually carrying down to the beading.

Above this tnere is placed a breaker strip, consisting of two or three layers of frictioned fabric impregnated in a rubber composition. This, too, is thickest at the center and tapers off to the sides, but ends at the edge of the tread. Finally, there is the surface covering, called by rubber men the tread; this contains very little pure rubber, being thickest at the center and extending with gradually decreased thickness almost down to the bead.

The last two of this series of layers constitute the real wearing surface of the tire, and when the surface is so worn that the breaker strip may be seen, it is time to have the tire retreaded. When the wear has gone through this, if the padding be fairly complete, retreading will still save the tire, but if wear has gone clear down through that so as to expose the fabric, the show must be run to a finish and then discarded.

All this construction can be noted in Fig. 547, which shows a section through a tire, with the inner tube in place, the section being taken so as to pass through the center of the tire valve. This should be borne in mind when examining this figure, for the location of the inner tube inside the tire, as previously described, is likely to be misleading.

Fig. 547 Section through Assembled Tire and Tube, Showing Construction and Parts of the Tire and Tire Valve

**Bead.** In the reference to tire construction, no mention has been made of the bead. This is a highly important part of the tire, for it is the part which holds it in place on the wheel. It is made of a fairly hard rubber composition, the fabric being carried down on the sides so as to cover it. In a cross-section, it has a shape very close to an equilateral

triangle resting on its base; around the wheel it is curved to fit the rim. The method of attaching the tire has a considerable influence on bead construction, since, in the clincher type of tire, in which the shoe must be stretched on over the rim, the bead must be extensible in order to insure easy mounting. In the quick-detachable and straight-side forms of tire there is no need for this stretching, so the bead can be made of stiff and rigid material as well as cut down somewhat in size.

The straight-side or Dunlop type of tire is seldom made with much of any bead, the layers of fabric being carried straight down. A more modern form of tire has a pair of woven-wire cables incorporated in the bead to make it stiffer and stronger, and this is said to have been very successful. As has been pointed out previously, this could be done only with the quick-detachable form, not with the clincher type.

In both the clincher and the quick-detachable forms, the bead holds the tire to the wheel by means of parts of the rim, which bear on it from above, as well as sidewise, the internal pressure when the tire is inflated pressing it against these parts very firmly.

Fig. 548. Views of Tire Valve, Showing Closed and Open Positions

In both the clincher and the quick-detachable forms, the bead holds the tire to the wheel by means of parts of the rim, which bear on it from above, as well as sidewise, the internal pressure when the tire is inflated pressing it against these parts very firmly.

**Tire Valves.** In Fig. 547 there is shown a section through the tire valve but on a small scale. As this is a very important part and little understood, a larger view is shown in Fig. 548. This is in two parts, *A* at the left showing the valve closed, and *B* at the right indicating the position of the various parts when the valve is open. Note that the lower part of the valve is hollow, so that air inside of the tire has access to the valve seat. Note that the valve is held down on this by the threaded portion above it. This valve seat

forms a slight taper which rests against an equally slight taper inside of the valve stem.

One condition of the tire valve holding air pressure is that the two valve seats be clean and smooth and free from scratches or cuts and foreign matter. Now it will be observed that the valve-seat portion of the valve has a hole through the center, in which the stem is a loose fit. This large hole passes all the way up through the threaded portion. The stem has a projection below the valve seat, which normally is held up against the bottom of the seat by the spring, this being strong enough to hold it up so tightly that no air can pass between the two. There are other conditions for valve tightness. The spring must be strong enough to hold these parts together; and the surfaces must be clean and true so that when held together, no air can get through.

*Action of Valve.* The action of the valve is this: When air is pumped in, it passes down around the central stem until it meets the projection, which it forces down against the pressure of the spring and, when there is air inside, against the pressure of the internal air. As soon as this is pressed down, the air passes in, and if the external pressure is stopped, as at the end of a stroke of the pump, the spring and the internal pressure push the projection back into place, and no air can escape. On the next pressure stroke of the pump, this is repeated, the whole process continuing until the tire is filled.

*Leaky Valves.* It will be noted that with a good clean spring, projection, and valve seat, the pressure of the air itself holds the valve tight. Thus, when a valve leaks, it is a sure sign that some part or parts of it are not in good condition. If the valve is not screwed down far enough, air can leak out around the valve seat, so that leakage may be remedied by screwing the whole valve farther down into the stem. If the valve stem is too tight a fit in the central hole, it may stick in a position which allows air to pass. This can be remedied by a drop of oil placed on the stem and allowed to run down it. But not more than one drop should be used as oil is the greatest enemy of rubber, and the tube with which the valve communicates is nearly pure rubber.

If the spring is too weak to hold the projection against the bottom of the valve seat, the valve will leak. This can be remedied

by taking out and cleaning the spring, also stretching it as much as possible. In general, however, the best plan of action with a troublesome tire valve is to screw it out and put in a new one. These can be bought for fifty cents a dozen, and every motorist should carry a dozen in a sealed envelope, also a combination valve tool. When trouble arises with the valve, or a tire leaks down flat with no apparent cause, screw out the valve with the tool, screw in a new one, make sure it is down tight, and pump up again. The few cents it will cost to throw away a valve, even if it should happen to be good, will be more then compensated for by the time saved. Another point is that the whole valve assembly is so very small that it is difficult to handle.

Washing tires often is a good practice, since water does them no harm, while all road and car oils and greases will be cleaned off, nearly all of these being injurious. Frequent washing will also serve to call the attention of the owner to minor defects while they are still small enough to be easily repaired, and thus they are prevented from spreading. When not in use, tires should be wrapped, so as to be covered from the light, and put away in a dry room in which the temperature is fairly constant the year round. They will not stand much sunlight, nor many changes in temperature. Cold hardens the tires and causes the rubber to crack. Heat has a somewhat similar effect and also draws out its life and spring.

In general, of all things to be cared for and repaired promptly, no one thing is of more importance than the tires. If this rule is kept in mind, better satisfaction in the use of the car will result. So, too, with other repair work; if tools and appliances are made available and repairs made as soon as needed, the car will be better understood and give more satisfaction than if the opposite course be pursued. A few months of use of a car will do more to emphasize this than any amount of talk. Keep your car in good condition and you will reap the benefits of the little work you do upon it.

## TIRE REPAIRS

### Repair Equipment

**Vulcanization of Tires for Repair Man.** In practically all of the following material the point of view is that of the professional repair man, or of the garage man about to take up tire repairs, as dis-

tinguished from that of the average owner or amateur repairer. The lesser tire injuries and their repairs are handled from an amateur standpoint in another part of this work.

Vulcanization, to the unitiated, sounds very mysterious, but it really is nothing more or less than cooking, or curing, raw gum

Fig. 549. Small Vulcanizing Outfit for Single Casing of Six Inner Tubes
*Courtesy of C. A. Shaler Company, Waupun, Wisconsin*

rubber. In the processes of manufacture a tire is cooked, or cured, all the component parts supposedly being united into one complete whole. A tire is repaired preferably with raw gum or fabric prepared with raw gum, and, in order to unite this to the tire, vulcanization or curing is necessary. The curing, in addition to uniting the parts

properly, gives the proper strength, or wear-resisting qualities, which raw rubber lacks.

**Types of Vulcanizing Outfits.** *Shaler Vulcanizer.* This curing, or cooking, is done by the application of heat, in a variety of ways. Generally, very small individual vulcanizers have a gasoline or alcohol cavity, holding just enough of the liquid so that when lighted and burned the correct temperature will be reached and held for the correct length of time. The larger units are operated by steam or electricity; the latter is preferred for its convenience, but the former is used by the majority of repair men. The source of heat is immàterial so long as the correct temperature is reached and maintained for the right lengh of lime. Too hot a vulcanizer will burn the rubber, while too low a temperature will not give a complete cure.

For the average small repair man, the outfit shown in Fig. 549 will do very nicely, at least to start with. This will handle a single casing or six tubes, or in a press of work, both simultaneously. This outfit is operated by gasoline, contained in the tank shown above at the right, but the same outfit can be had with pipe arrangements for connecting to a steam main, or for electric heating. In the case of either gasoline or steam, there is an automatic temperature controlling device which is a feature of the Shaler apparatus. As shown, casings are repaired by what is known as the "wrapped tread method", the repair being heated from both inside and outside at once, the outside being wrapped. Tubes are handled on the flat plate, shown in the middle of the framework, the size of which is 4½ by 30 inches, this being sufficient, so the makers say, to handle six tubes at once.

*Haywood Vulcanizer.* For larger work, a machine something like the Haywood Master, shown in Fig. 550, is excellent. This is a self-contained unit, carrying its own gasoline tank, steam generator, and other parts. It handles four casings at once, while the tube plate *G*, 5 by 18 inches, is large enough for from three to four tubes, according to the allowance per tube made in the Shaler outfit. The separate vulcanizers are not designed for the same part of a casing, a side wall and bead vulcanizer being shown at *D*, a sectional vulcanizer for large sizes at *E*, a sectional vulcanizer for small and medium sizes at *F*, and a side wall and bead vulcanizer for both clincher and straight-side tires at *H*. The gasoline tank is marked *C*, with vertical pipe in which is the gasoline cut-off valve *K*. This

leads down to the gasoline burner *M*, where the gasoline in burning vaporizes the water into steam. The water gage *L*, which indicates the amount of water available, is placed on the side of the steam generator *A*. Above this steam generator is the steam dome at *B*,

Fig. 550. Master Vulcanizer with Self-Contained Steam Generator
*Courtesy of Haywood Tire and Equipment Company, Indianapolis, Indiana*

from which the steam pipes lead to the various molds. The returns, or rather drips, will be noted, also the steam gage (not marked) and the cut-off valve in the supply pipe to the sectional molds. In addition to the molds shown and a full supply of parts and tools, sectional vulcanizers for 2½- and 3-inch tires, relining mold for 2½-, 3-,

and 3½-inch tires, and relining mold for 4-, 4½-, 5-. and 5½-inch casings come with the device.

This outfit with the extra molds, described but not shown, gives a very complete equipment for the small shop doing average

Fig. 551. Battery of Vulcanizing Mold for Various Sizes of Tires

repairing. In fact, when a shop outgrows this type of equipment, it must specialize in tire work and purchase special equipment.

**Separate Casing Molds for Patch Work.** In the way of separate molds for casings, an excellent example of the localized heat type is shown in Fig. 551. By this is meant the form designed to vulcanize a small short section of a tire. The illustration shows five sections capable of handling, respectively, 2¼-, to 3-inch (motorcycle), 2½- to 3-inch (small car), 3½- to 4-inch, 4½- to 5-inch, and 5½- to 6-inch tires, thus covering the entire range. These molds have a special arrangement in that the heating portion is divided into three sections, into each of which steam can be admitted separately. This allows the use of one, two, or all the sections, according to the nature of the repair.

In Fig. 552 is shown how it is possible, with this apparatus, to vulcanize the tread portion only by admitting steam solely to the larger bottom steam chamber around the tread, similarly, with the right-hand bead or side wall or the left-hand bead or side wall. When a complete section is to be vulcanized, all sections are opened. The importance of this will be realized in a simple consideration of the fact that the tire itself has already been vulcanized and further heat is not only not good for it, but is distinctly bad, as it deteriorates the rubber. Where the heat

Fig. 552 Section of Vulcanizer, Showing Steam Cavities

is needed, however, is not the raw rubber which has just been added at the repair point, this being practically useless until it has been cured.

**Vulcanizing Kettles.** *Horizontal Type.* When it comes to vulcanizing an entire tire, as, for instance, when a new tread has been put on, or other very large repair, what is known in the trade as a "kettle" is needed. This is simply a heavy steel tank, large enough to take one or more entire tires, steam being admitted to its interior to vulcanize them. The kettle shown in Fig. 553 has a capacity of two casings 36 inches in diameter or smaller. It is of the type in which no bolts or nuts are used for fastening the cover, this being held fast by the projecting lugs which lock under other projections on the top of the kettle when the cover is turned. A special rubber packing ring also is used, Fig. 554, effectually sealing the kettle against steam leakage. This kettle resembles a doughnut in shape, the tires lying within the circular cavity.

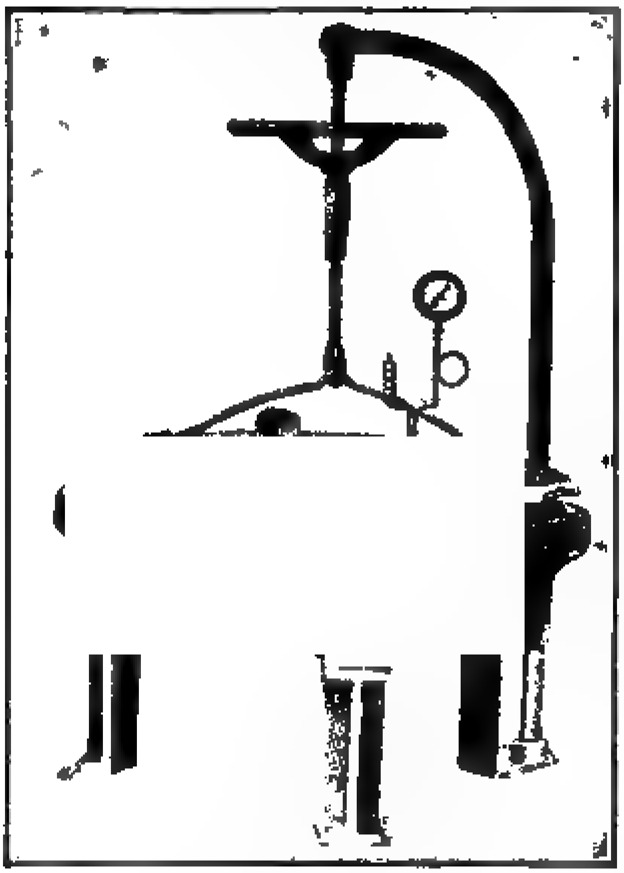


Fig. 553. Vulcanizing Kettle, Horizontal Type

Fig. 554. Section of Horizontal Vulcanizing Kettle

*Large Vertical Type.* When the work goes beyond the capacity of size and type of tank or kettle shown in Fig. 553, which will handle

two casings at a time, and at least two, perhaps four, kettles full an hour, that is, from 40 to 75 casings a day, it becomes necessary to use a larger type of kettle, made in vertical types only. These consist simply of large round steel shells with hinged heads, into

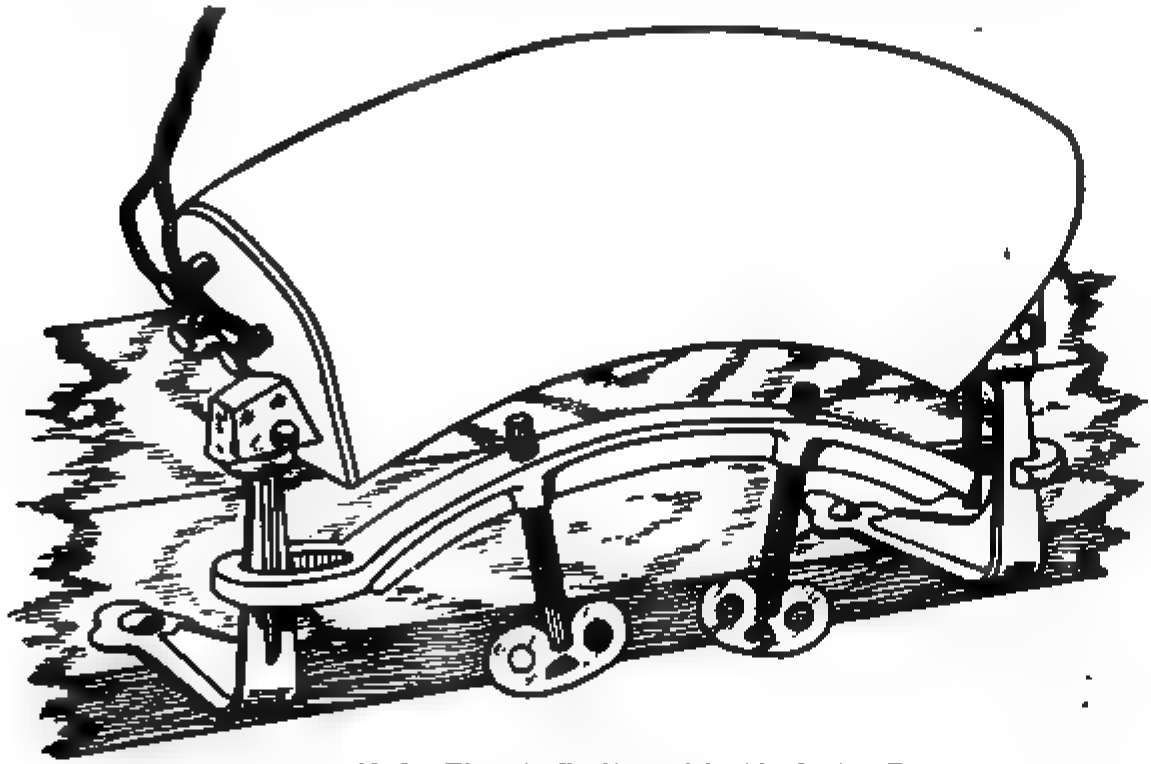


Fig. 555. Shaler Electrically Heated Inside Casing Form

which the tires can be rolled and piled, after which steam is admitted to the whole interior. They vary in size from 36 inches inside diameter by 24 inches in length to 48 inches diameter by 40 inches in length.

**Inside Casing Forms.** Another requisite of the tire specialist is an inside casing form, such as is shown in Fig. 555, or something similar. Many tire repairs are inside work, and even on those which are external, it is important to have an inside form against which the tire can be pressed and firmly held while vulcanizing. This particular form is heated by electricity, the wires being shown at the left; it is 14 inches long and has an external shape to fit the inside of all casings.

Fig. 556. Side-Wall Vulcanizer

**Side-Wall Vulcanizer.** A shop doing a great deal of work can use to good advantage the side-wall vulcanizer shown in Fig. 556.

It has a single central member through which the steam passes, an also has bolted-on side plates, the insides of which are formed to su either clincher or straight-side tires. In the figure, the side plates ar not both in place, one being shown on the work table below. Th brace shown is used to remove the clamping nuts quickly and easily This form is very useful on all side-wall or bead operations. It applie greater pressure along these parts of the tire than an air bag; it exactl

Fig. 557. Retreading Vulcanizer with Tire in Position
*Courtesy of Haywood Tire and Equipment Company, Indianapolis, Indiana*

fits the tire, and the size and shape make it possible to vulcanize a 36-inch tire in four settings.

**Retreading Vulcanizers.** Retreading vulcanizers differ from the sectional molds of Figs. 549, 550, and 551 in that the heat is applied at one particular point or, rather, strip along the middle of the top surface of the casing and extending down only as far as the side walls. Such a device, shown in elevation in Fig. 557, and in enlarged sectional detail in Fig. 558, is used solely for retreading or vulcanizing a new tread strip around the tire. The complete unit extends around about one-third of the whole tire surface so that

hen putting on a complete new tread the mold must be used three mes. The section, Fig. 558, is numbered as follows: casing, 2; .ner mold, 1; new tread to be vulcanized, 3; vulcanizer proper, 4; amp, 5; and steam space within which the heating is done, 6.

**Layouts of Equipment.** There are two ways of installing an utfit somewhat like that just described, namely, by the non-return ystem and by the gravity-eturn system.

*Non-Return Layout.* A ypical installation according o the non-return system is hown in Fig. 559. A steam rap must be placed in the ystem to remove the water and discharge it either into he sewer or into a tank so hat it can be used again. In the figure there is shown a tube plate, a three-cavity sectional vulcanizer, two inside molds, and a medium size kettle of the vertical type placed in order from right to left. A pressure-reducing valve is shown which permits the use of a higher pressure in the boiler, thus maintaining an even steady pressure on the vulcanizers regardless of fluctuations at the boiler.

Fig. 558. Section of Retarding Vulcaniser
*Courtesy of Haywood Tire and Equipment Company, Indianapolis, Indiana*

*Gravity-Return Layout.* When the coil steam-generator or flash type of boiler is used, the gravity-return system is utilized, this being a method of piping by means of which the condensed steam is returned to the coil heater to be used over again. This makes it necessary to set the apparatus so that the water of condensation will run back to the coil heater, which means that the pieces must be in a series, each successive one being set a little lower down to the boiler. Figs. 560 and 561 show a side view and plan view, respectively, of a small

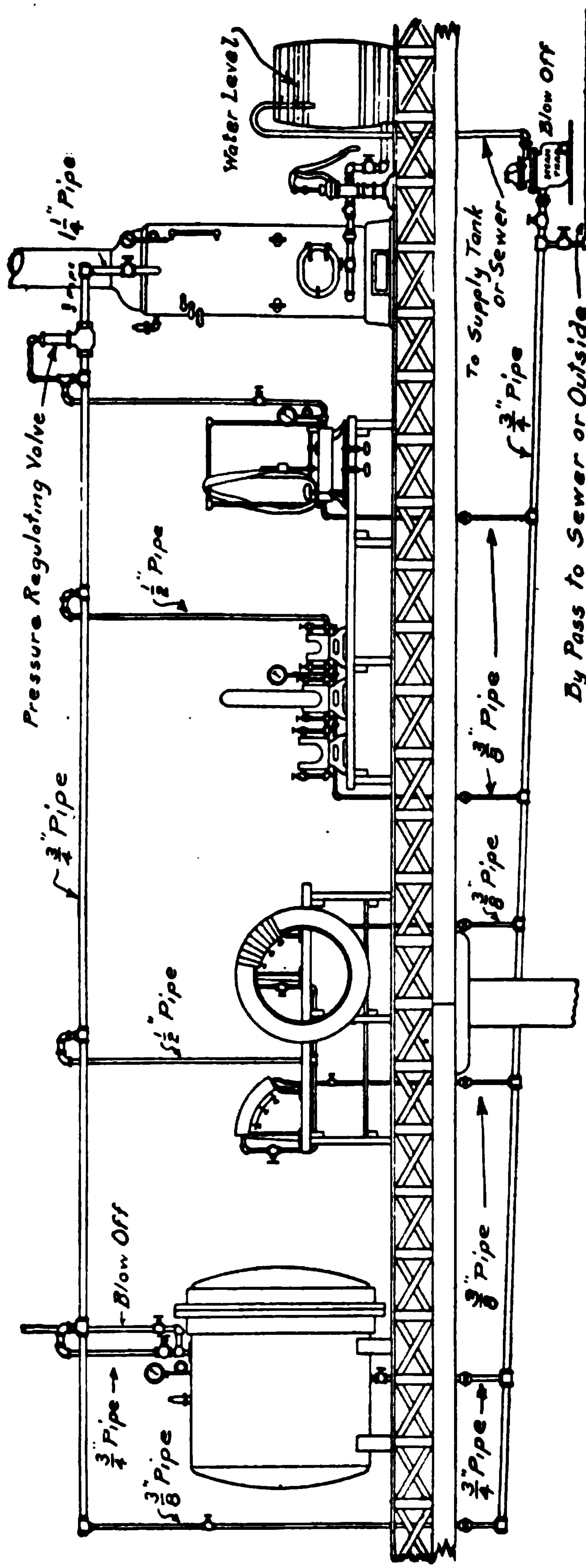



Fig. 559. Diagrammatic Layout for Non-Return Vulcanizing Plant

plant arranged on this plan. The outfit consists of the coil heater, which may be fitted to burn gas or gasoline, two inside molds, a large tube plate, and a three-cavity sectional vulcanizer. The outfit

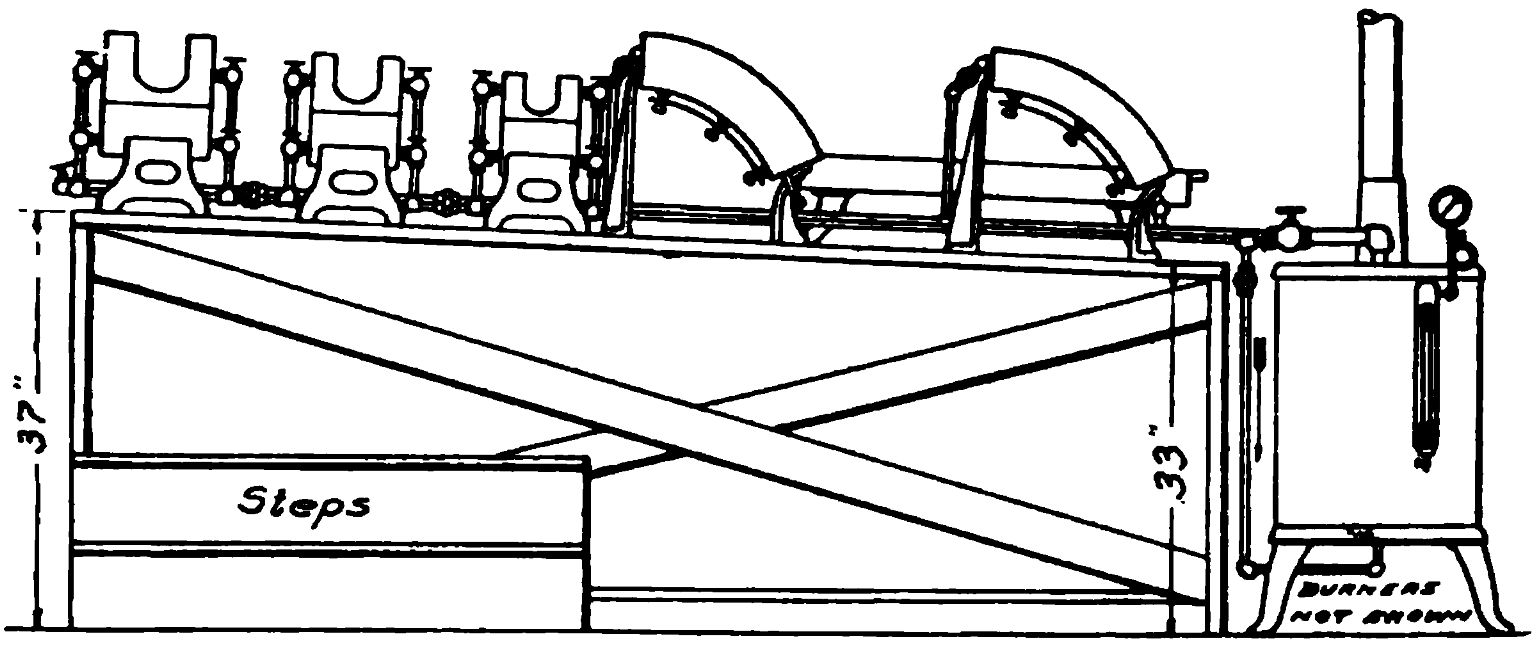



Fig. 560. Elevation of Gravity-Return Vulcanizing Plant

differs from Fig. 559 only in the absence of the kettle; on the other hand, the tube plate in Fig. 560 is larger.

**Small Tool Equipment.** In addition to these larger units, the well equipped tire repair shop should have a considerable quantity of small tools, among the necessities being those shown in Fig. 562. At *A* is shown a flat hand roller and at *B* a concave roller. *C* shows an awl, or probe, which is used for opening air bubbles and sand blisters. *D* is a smooth stitcher; *F* a rubber knife, of which two sizes are advisable, a large and a small; and *G* a 10-inch pair of shears for

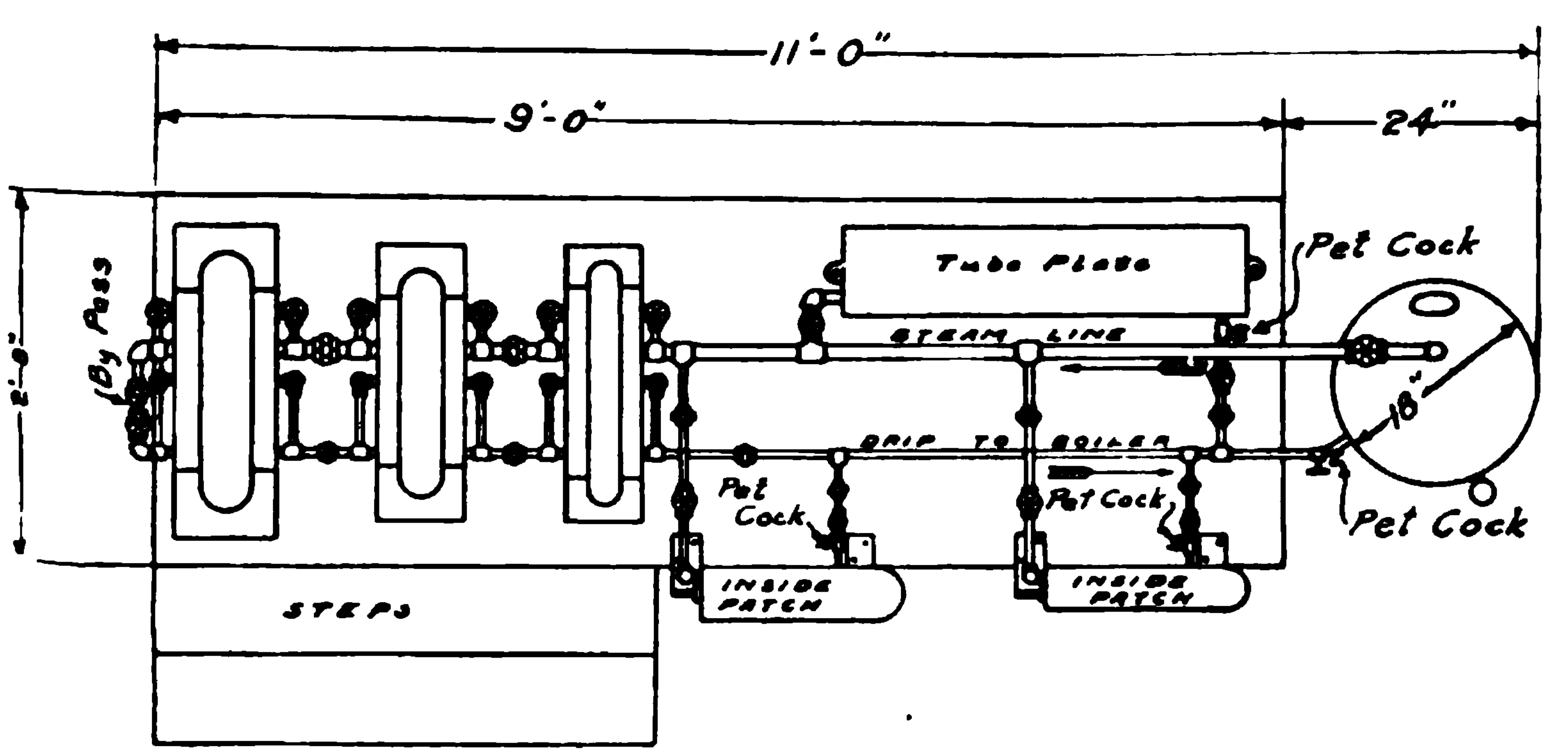



Fig. 561. Plan View of Gravity-Return Vulcanizing Plant

trimming inner tube holes, cutting sheet rubber, etc. *H* is a steel wire brush for roughing casings by hand; a preferable form is a rotary steel wire type driven by power at high speed. *I* is a similar

wire brush for roughing tubes; and *J* another brush with longer wires, also for roughing casings; *K* is a tread gage for marking casings to be retreaded; and *L* a fabric knife necessary in stepping down plies of fabric. *M* is a pair of plug pliers for placing patches inside of small tube repairs; *N* is a cement brush for heavy casing cement, another very much smaller and lighter one—preferably of the camel's hair type—being used for tube cement. *O* is a hand

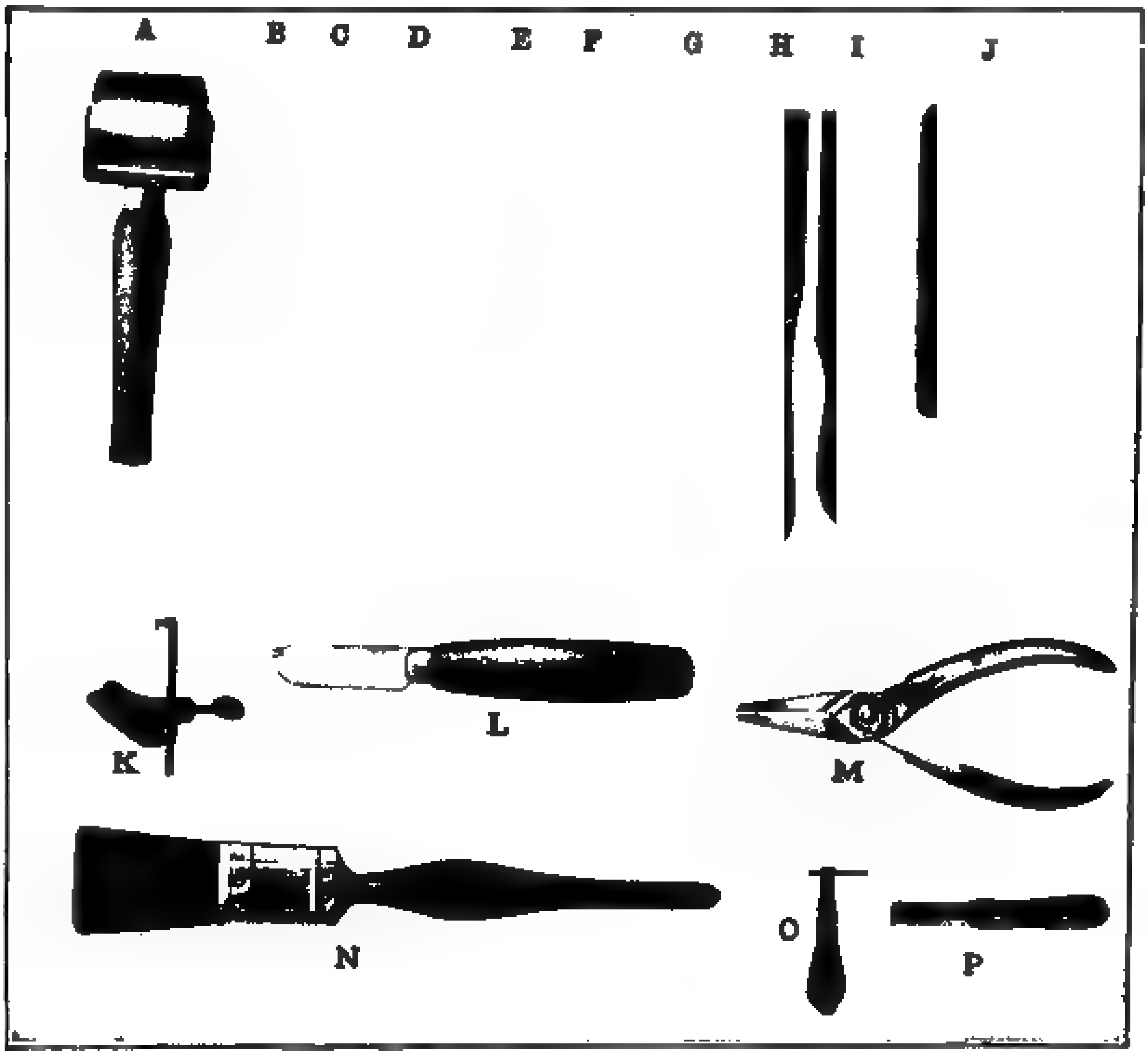



Fig. 562. Collection of Tools Necessary for Vulcanizing Work

scraper and *P* a tread chisel; *Q* performs a somewhat similar function, being a casing scraper for cleaning the inside of a casing preparatory to mending a blowout.

In addition to the small tools shown in Fig. 562, it is necessary to have several tube-splicing mandrels; a large number of various sizes and shapes of clamps for all purposes; rules, try-squares and other measuring tools; tweezers for handling small patches, tools for recutting threads on tire valves; tire spreaders, for holding casings

open when working inside; a casing mandrel or tire last of cast iron for holding a casing when making repairs; a tread roller for rolling down layers of raw stock evenly and quickly; a considerable amount of binding tape; thermometers; and such motor-driven brushes, scrapers, etc., as the quantity and quality of the work warrant.

**Materials.** Each repair shop must carry such a supply of tire-repairing material as the nature and quantity of its business demands. Among other things may be mentioned: Tread stock, rebuilding fabric, single-friction fabric, cushion stock, breaker strips, single-cure tube stock, combination stock, cement, quick-cure cement, soapstone, valve bases, valve insides, valve caps, complete valves, vulcanizing acid, various tube sections, tire tape, cementless patches, as well as many other tire accessories to sell. Many good tire-repair shops find a legitimate use for special tire-repairing preparations on the order of Tire-Doh.

### Inner Tube Repairs

In general, all tire repairs come under one or more of the following headings; puncture; blowouts; partial rim cut or rim cut all around; and retreading or recovering, and relining.

**Simple Patches.** Under the heading of punctures are handled all small holes, cuts, pinched tubes, or minor injuries. Generally, these can be repaired by putting on a patch by means of cement, or with cement and acid curing. When well done, this method is effective. This kind of a job seldom comes to the repair man, and, when it does, it is principally because the owner is too lazy to do the work. About the only two cautions necessary are relative to cleanliness and thoroughness. The tube and patch should be thoroughly cleaned. Again the patch should be large, well cemented, and the cement allowed to dry until just sticky enough to adhere properly. Many a simple patch of this kind has been known to last as long as the balance of the tube.

**Large Patches.** *Cleaning the Hole.* Whenever the hole or cut is large, it is recommended that the repair be given more serious attention and vulcanized. The ragged edges of the rubber should be trimmed smooth with the tube shears or knife, the minimum amount of rubber being cut away. The hole, however, should be made large enough to allow the insertion of an inside patch. Then

the tube around the hole should be cleaned thoroughly. This is best done with a cloth wet with gasoline, cleaning not only the outside but the inside around the hole and at the edges. In order to make a good job of this, it should be gone over several times; the larger the hole the more care should be used in cleaning around it.

*Preparing the Patch.* Having the hole well cleaned and ready, these cleaned parts should be painted with two coats of vulcanizing cement, which is allowed to dry. This must be thoroughly, not partly, dry. Then the proper patch is selected, the smaller size being sufficient for small patches, while in the case of large repairs, the patch should be from ½ to 1 inch larger all around than the hole. If this is not a prepared patch, one side should be cemented just as the tube was previously. If a prepared patch is used, the semi-cured side should be placed in, that is, with the sticky or uncured side toward the tube from the inside.

When the cement on the patch is just sticky enough, it should be inserted and the tube pressed down against it all around, slowly and carefully so as to get good adhesion. Next the cavity about the inside patch is filled with gum or pure rubber, preferably in sheet form as it comes for this purpose. This is filled in until the surface is flush. It is preferable to use a little vulcanizing cement to hold this rubber in place, particularly if a piece of sheet gum is cut to fill the hole.

*Vulcanizing the Patch.* The repair is now about half completed and is next vulcanized. The length of time, if steam is used, varies with the amount of steam pressure; if the portable gasoline or alcohol type of vulcanizer is applied the time varies with the temperature. As this time variation is so wide, it is impossible to give an invariable rule. Thick tubes require a little longer than thin ones, large patches longer than small ones, wide patches more than narrow, etc. The vulcanizing must be carefully and thoroughly done, and, as the success of the whole job depends upon this one process, the arrangement of the tube on the plate, of the soapstone on the new rubber and on the vulcanizer to prevent adhesion, of the wood or rubber pad above the patch, of the clamp and its pressure, should all have careful attention. With 60 pounds steam pressure available, from 10 to 12 minutes is about right, with 75 pounds from 8 to 10 minutes. In any case, the rubber should be cured just firm enough not to show

a slight indentation from the point of a lead pencil. This is a good test to use at first, although after a short experience, the workman will be able to judge of the condition from the feeling, color, and general appearance of the patch.

When the size of the plate is small, the tubes should be held up above it out of the way, partly to allow the full use of the plate surface, but also to keep the tubes from being damaged.

**Inserting New Section.** *Preparing the Tubes.* In case the damage to the tube is too great to permit the use of a patch, for instance, in case a blowout makes a wide hole perhaps 7 inches or more long, in an otherwise good tube, it is advisable to cut out the damaged section and insert a new section in its place. Sometimes old tubes of the same size can be used for this, but, if not, sections can be purchased from the larger tire and rubber companies.

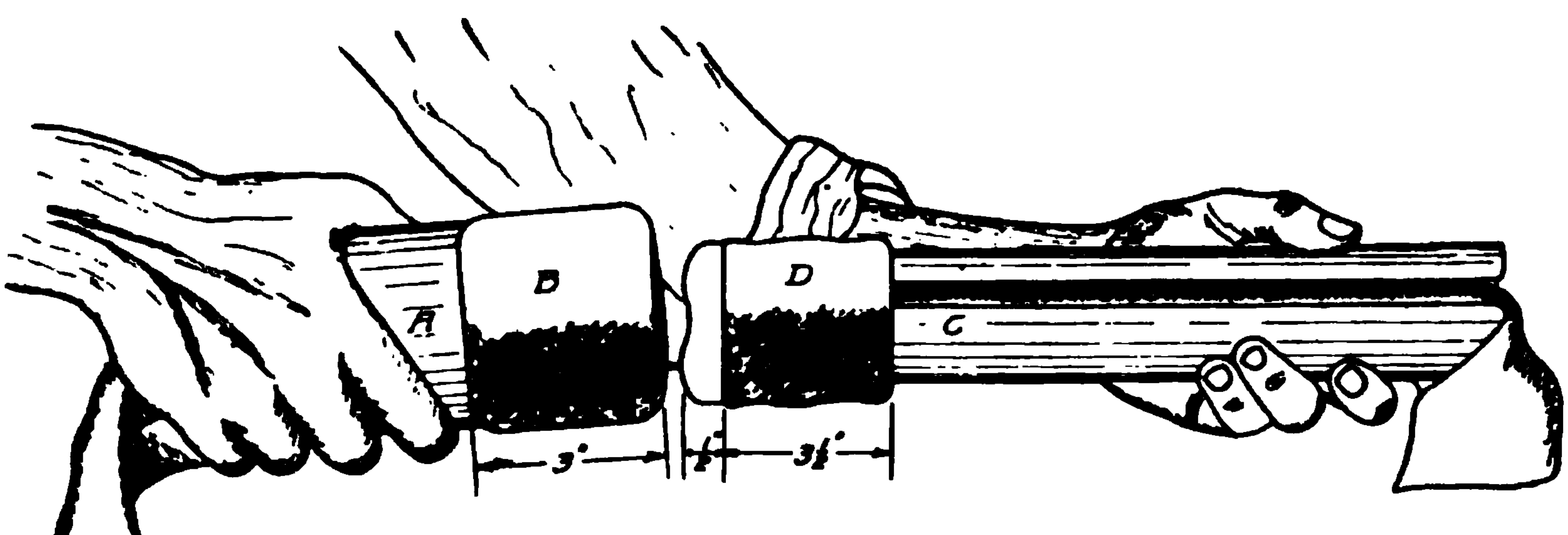



Fig. 563. Sketch Showing Method of Inserting New Section in Inside Tube

In the repair, proceed as follows: After cutting out the damaged section, bevel down the ends very carefully, using a mandrel to work on and a very sharp knife. As the appearance and, to a large extent, the value of the repair will depend upon these beveled ends, this should be done in a painstaking manner. Next select the tube section and cut it to size, that is, from 5 to 6 inches longer than the section which was cut out and which this patch is replacing. This allows 2½ to 3 inches for the splice at each end. Bevel the ends of the tube as well, and, after beveling all four ends, roughen them with a wire brush or sandpaper.

*Making the Splice.* Having the tube and repair section beveled and buffed, the ends to be joined should be coated with one heavy or two light coats of acid-cure splicing cement. With the tube and patch properly placed on the mandrels—tube on the male and patch on the female—turn back the end to be repaired and the end to be

applied as shown in Fig. 563. At $A$ is shown the female mandrel on which is the patch $B$, turned back from the end of the mandrel about the right distance, say 3 to 3½ inches. On the male mandrel $C$ the tube $D$ has been turned back about 7 to 7½ inches, then turned back again on itself about 3 to 3½ inches.

Just as soon as the cement has dried thoroughly on the tube, apply a coat of acid to the patch and immediately place the two mandrel ends together and snap, blow, or push the end of the patch over on to the end of the tube. This frees the female mandrel, which can be laid aside. Immediately wind the patched portion (still on the male mandrel) with strips of muslin or inner tubing. In 15 to 20 minutes the cement will have formed a permanent union, the wrappings can be removed, and the tube withdrawn through the slot in the mandrel.

Fig. 564. Section of Tire, Showing Forms of Troubles

This done successfully, the whole operation is repeated for the other splice. If the splice does not cure together well, it indicates either that the acid supply is poor or else the splicing was not done quickly enough after applying the acid.

## Outer Shoe, or Casing, Repairs

**Classifying Troubles.** Some of the common tire troubles—those of the inner-tube variety just discussed, and casing troubles as well—can be clearly shown by suitable illustrations. For example, a section through the tire showing how the troubles occur is some-

times very useful, as shown in Fig. 564. Here the pinched tube and blowout are indicated, the results of these on the inner tube and also their method of repair having just been described. These troubles together with punctures, leaky valves, and porous rubber in the tubes about cover the extent of inner tube troubles. Because of their more complex construction, casings have more numerous and more varied troubles, which, consequently, are more difficult to repair. The more common casing troubles are blisters, blowouts, rim cuts, and worn tread, the latter indicating the necessity for retreading. These will be described in order.

**Sand Blisters.** The sand blister shown on the side of the tire, Fig. 564, is brought about by a small hole, such as an unfilled puncture hole, in combination with a portion of the tread coming loose on the casing near this hole. Particles of sand, road dust, dirt, etc., enter, or are forced into, this hole and move along the opening provided by the loose tread. Soon this becomes continuous and the amount of dirt within the break forces the surface rubber out in the form of a round knob known as a sand blister. This is cured by cutting open the blister with a sharp knife on the side toward the rim and picking out all dirt within. When the recess is thoroughly cleaned, the hole and the radial hole in the tire tread nearby should be filled with some form of self-curing rubber filler, a number of kinds of which are sold. The double benefit of this is to close the hole so that the trouble is not repeated and to keep out moisture which would ultimately loosen the entire tread.

Fig. 565. Method of Preparing Layers of Fabric or Patching Blowouts—Inside Method

**Blowouts.** The blowout, which is perhaps the most important casing repair, may be made in two ways: the inside method, in which

the whole repair is effected on the inside; the combination inside and outside method.

*Inside Repair Methods.* Refer back to Fig. 564 for the general tire construction and to Fig. 565 for this particular case, the inside of the tire is held open by means of tire hooks and the inside fabric layers or plies removed for a liberal distance on each side of the opening. As shown in Fig. 565, a lesser amount of the second layer should be taken than of the first, and still less of the third and each subsequent one. On 3½- and 4-inch tires it is not advisable to remove more than two plies; on 4½-inch tires three, as shown; and on the larger sizes four plies. The edge of each layer of fabric should be beveled down thin, as well as the material directly around the blowout.

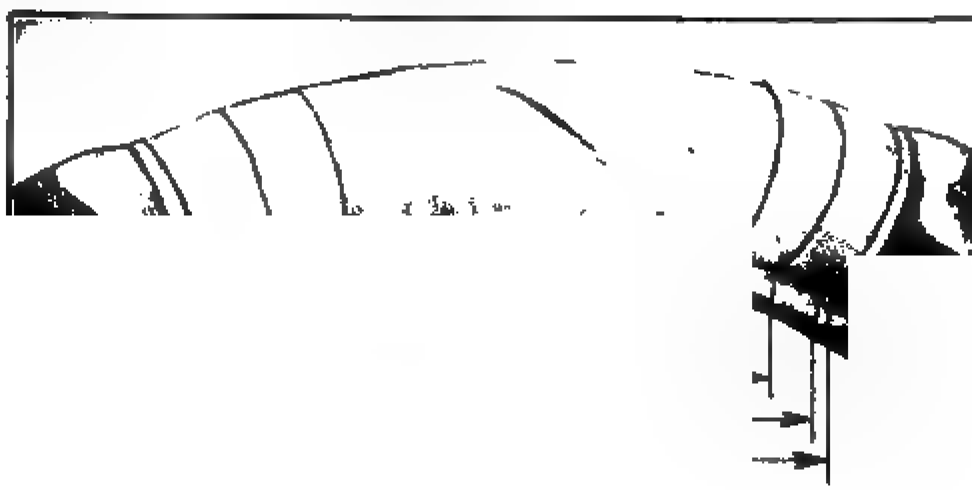


Fig. 566. Method of Preparing Fabric for Blow-Out Patch—Inside and Outside Method

Apply a coat of vulcanizing cement and when it has dried, say for an hour, apply another. When this has dried enough to be sticky or tacky, fill as much of the hole as possible with gum. When this is filled in level, apply the fabric patch. This is made up to match the fabric cutout; that is, if three layers are removed, it should consist of three plies s
bareback fabric unfric
extend 3½ to 4 inches b

When this is prope
tire is placed in a secti
with muslin strips to ho
from the inside. This
and easy one, but it is
not as effective as the i

*Inside and Outside Method.* In the inside and outside method, the material is removed from the outside, stepped down, and beveled in the same manner as for the method just described. Fig. 566 shows a tire with a medium size blowout, which has been stepped down for a sectional repair, four plies having been removed. The rule for the number of plies to remove is about the same as before, except that in the larger sizes this should depend more on the nature of the injury. It should be noted, however, that in this case the plies have all been removed right down to and including the bead. This is done to give the new fabric a better hold and to make a neater job and one that will fit the rim better. Give the whole surface two good coats of vulcanizing cement, allowing it to dry thoroughly.

Apply the same number of plies of building fabric as were removed, with the addition of chafing strips of light-weight fabric at the bead. Over this building fabric apply a thin sheet of cushion gum, slightly wider than the fabric breaker strip; then a thickness of fabric breaker strip over this; and then over this fabric another sheet of gum, slightly narrower than the previous sheet. All this, however, should be built up separately and applied as a unit and not one at a time, as described. These several plies should be well rolled together on the table. All edges should be carefully beveled off, especially the edges of the new gum where it meets the old, as it is likely to flow a little and leave a thin overlap which will soon pick loose.

No fabric is removed from the inside, but the hole is cleaned, its edges beveled, then filled with tread gum, and the inside reinforced with a small patch of building fabric; over this lay two plies of building fabric of considerable size. Now the whole casing is placed in a sectional mold, a surface plate applied to the outside, and heat applied both inside and outside. This will heat the tire clear through and make a good thorough job of curing.

**Rim-Cut Repair.** *Partial Cut.* To repair a partial rim cut, one or two plies of the old fabric are removed, unless it is severe, when three plies may be taken off. This is removed right down clean as explained under Blowout Repairs, and the cement and new materials applied in the same way, with the omission of the fabric breaker strip. However, care should be used to carry all building fabric layers not only down around the bead to the toe but up on

the inside far enough to secure a good hold and ample reinforcement. If this should make the rim portion somewhat more bulky, remember it was a case of doing this or getting a new tire.

*Complete Rim Cut.* Where the rim cutting is continuous, the old side-wall rubber is removed up to the edges of the tread, and the old chafing strips and one ply of old fabric to about an inch above the beads removed also. Cut through the side-wall rubber all around, but be very careful not to cut into the fabric body, or carcass. The whole of the side wall and chafing strips can be removed in one operation. Apply two coats of cement and, after this is thoroughly dry, put on a patch consisting of one ply of building fabric, one ply of chafing strip, and a surface, or outside, ply of new tread gum. This is made on the table and the parts thoroughly rolled together. When completed, vulcanize in a sectional mold with sectional air bag and bead molds or endless air bag; apply to a split curing-rim wrap, and vulcanize in heater or kettle. The tire is repaired, but not vulcanized, and, with the ends of the three applied plies of material loosened to show, may be seen in Fig. 567.

Fig. 567. Method of Handling Rim Cuts

**Retreading.** Retreading is a job which must be done very carefully, not only because of the job itself, but also because this is probably the most expensive single job which can be done to a tire, and the worker should make sure before starting that the wire warrants this expense. It should have good side walls and bead, and the fabric should be solid and not broken apart.

*Repairing the Carcass.* In the usual case, it is advisable to remove not only the surface rubber and fabric breaker strip, but also the cushion rubber beneath the breaker strip, that is, the tire

should be cleaned off right down to the carcass, and the latter cleaned thoroughly. As the rubber sticks, a rotary wire brush will be found useful and quick. However, this should be used carefully so as not to gouge the carcass. After buffing, the loose particles of rubber should be removed with a whisk broom or dry piece of muslin. In this cleaning work the carcass should be kept clean and dry. Apply two coats of vulcanizing cement and allow both to dry; the first should be a light coat to soak into the surface fabric; the second should be a heavy coat.

*Building Up the Tread.* In building up the tread, it should not be made as heavy as the former tread, as the old worn and weakened carcass cannot carry as heavy a tread as when new. Furthermore, it takes longer to vulcanize a heavy tread and presents more opportunity for failure. In the building-up process, the proportioning of weights is important, and should be taken from the tabulation below, which represents years of experience in tire repairing:

| Size of Case (in.) | Ply toward Fabric (in.) | Second Ply (in.) | Third Ply (in.) | Fourth Ply (in.) | Fifth Ply (in.) | Last Ply Over All | Complete Tread Consists of |
|---|---|---|---|---|---|---|---|
| 3 | 2¾ | 3½ | | | | *See Note | 3 plies |
| 3½ | 2¾ | 3½ | 4¼ | | | *See Note | 4 plies |
| 4 | 3¼ | 4 | 4¾ | | | *See Note | 4 plies |
| 4½ | 4 | 4¾ | 5½ | | | *See Note | 4 plies |
| 5 | 4¼ | 5 | 5¾ | 6½ | | *See Note | 5 plies |
| 5½ | 4¾ | 5½ | 6¼ | 7 | 7¾ | *See Note | 6 plies |
| 6 | 5¼ | 6 | 6¾ | 7½ | 8¼ | *See Note | 6 plies |

* Note—Determined by condition of case after buffing and cementing.

| Size of Case (in.) | Width of Breaker Strip (in.) |
|---|---|
| 3 | 1⅝ |
| 3½ | 2⅛ |
| 4 | 2½ |
| 4½ | 3 |
| 5 | 3⅝ |
| 5½ | 4 |
| 6 | 4½ |

This tread strip is built up on the table with exceeding care, all edges being rolled down carefully. When the strip has been prepared and the carcass is ready for it, one end should be centered on the carcass, and then the balance of the strip applied around the circumference, being careful to center it all around, as the workman in Fig. 568 is doing. After it has been applied all around, it should

be rolled down carefully, all air pockets opened with a sharp pointed awl, and the gum at the edges of the plies rolled down with the corrugated stitcher. When ready, vulcanize in a kettle, using an endless air bag with tire applied to a split curing-rim, and wrapped—preferably double wrapped—all around.

**Use of Reliner.** Many a casing which appears good on the outside but which really is unsafe because of fabric breaks on the inside
orarily prolonged,
r. By this is not
and fabric reliner
a regular built-up
ized in place so as
to be an integral part of the tire. For ordinary breaks, use a single ply of building fabric on a casing which has been entirely cleaned out and which has had two coats of vulcanizing cement thoroughly dried
eak, use two plies
fit; the under ply
des and coated on

Fig. 568. New method of Putting on New Tread

one, and the upper ply should be frictioned on one side only, the side toward the tube being bareback. Use an endless air bag for internal pressure, apply to a split rim, wrap, and vulcanize in a kettle from 35 to 45 minutes at a steam pressure of 40 pounds.

**Summary.** By the application of parts of the foregoing instructions and the use of much common sense, coupled with a knowledge of the construction, use, and abuses of tires, the repair man will be able to handle any form of tire repair brought to him. In starting

out, perhaps he could not do a better thing than to take an old tire apart to see just how it is constructed. This will give a much more clear idea than any number of diagrams, sketches, or photographs.

The tire repair man should remember, too, that this is no longer a game, but that, by means of scientific apparatus and the application of correct principles, it has been brought up to a high state of perfection; an expert can predict with reasonable accuracy what will happen in such and such a case, if this and that are not done. In short, the tire-repairing business within the last few years has been brought up to a stage where it, or any part of it, is a dependable operation. The tire repair man should handle all his work from this advanced point of view; it will pay the largest dividends in the long run.

## SUMMARY OF INSTRUCTIONS

**Q. What are the units comprising the final-drive group?**

A. Universal joints; driving shaft; final gear reduction; axle-shaft differential; axle enclosure; torque rod, or tube, or substitute tor this: radius rod, or tube, or substitute for this; brakes; wheels; and tires.

**Q. Why are these called the final-drive group?**

A. Because they constitute the final drive of the car, beyond the power-producing unit, the engine; the connecting and disconnecting unit, the clutch; and the speed-changing unit, the transmission.

**Q. What is the function of the universal joint?**

A. In the final-drive group, it is used to transmit power at an angle, as, from a horizontal-transmission shaft to an inclined-driving shaft.

**Q. How does it do this?**

A. The construction is such that the driving shaft is attached to one set of pins, while the driven shaft is attached to another, the axes of these intersecting in a common point. As the driven shaft can turn about its pins in one plane and, with the complete joint, about the driving shaft pins in another, as well as combinations of the two, complete freedom, or universal movement, is assured.

**Q. What are the power losses in a universal?**

A. In a well-designed and fitted universal joint, working practically at zero angle, there is no loss, but as the angle increases, the loss increases until at about 20 degrees, it may reach 2 or 3 per cent.

**Q. Why is such a joint needed?**

A. The final drive must be at the center of the rear axle, which is comparatively low, say 17 inches with 34-inch wheels or 18 inches with 36-inch wheels, while the power must originate at the engine which cannot be set as low as this, that is, the power must be generated at a higher level than that at which it is used. An inclined shaft and universal joints must be used somewhere in the system.

**Q. What other considerations necessitate universal joints?**

A. The engine level varies little, while the rear end of the chassis varies up and down through a considerable range. In addition, the rear end carries perhaps 85 per cent of the load and sustains greater road shocks because of this fact. The design is such as to keep the front, or engine, end as quiet and as nearly stationary as is possible. These considerations necessitate a flexible connection between the two ends, so that one can move frequently and through considerable distances, while the other moves seldom and through very small distances. In addition, the rear end must sustain considerable side sway, so that freedom in a sidewise direction is necessary. The only way in which these necessities can be obtained is through the use of universal joints.

**Q. What is a slip joint?**

A. One which will allow sliding, or slipping, of one part or shaft within the other. Thus, under certain restraining conditions the rise and fall of the rear end may mean approaching or receding of that end to and from the front portion. With a slip joint, this is made easy.

**Q. What is the usual form of a slip joint?**

A. Generally, this takes the form of a squared shaft within a squared-out housing, although sometimes the square is rounded off to give a slight universal action.

**Q. What is the modern form of universal joint?**

A. A thin flexible disc of steel, leather, fiber, or laminated fabric, with the driving shafts bolted to two opposite points and the drive shaft bolted to two others between them has been found to be much simpler, lighter, cheaper, and better than the average universal, although it allows only limited angular motion. The engine is being gradually lowered, while the rear wheels are constantly being increased in size; so the difference of level is not as great as it was, and there is less need for the full universal.

**Q. What is the biggest advantage of these to the repair man?**

A. They allow the removal of a driving shaft, or a unit on either side of such a joint much more quickly and easily, with less work, than any other form, similarly, in replacement after the repair is completed. In addition, they have no loose parts to be lost or mislaid with consequent trouble and delay of the work.

## DRIVING SHAFTS

**Q. What is the usual type of driving shaft?**

A. The usual driving shaft is of small diameter and solid. Cold rolled steel is used on the lower priced cars, but forged steel machined at the ends (at least) is used on the better cars. On many of the most expensive machines, the shaft is fairly intricate in shape and is machined all over after forging, sometimes ground after hardening.

**Q. What would be the advantage of a spring shaft?**

A. Being flexible, it would cushion the shocks so that none of these reached the engine. Such shocks as are induced by jerking the throttle wide open, or stepping on the accelerator pedal suddenly or, on the other hand, a sudden application of the brakes.

**Q. What is its real disadvantage?**

A. Being small, the owner of the car and the driver would always mistrust it, and would not feel free to drive as they would with a larger and more dependable shaft.

### Torque and Radius Rods

**Q. What is torque?**

A. Torque is turning effort, or force, applied to rotation, in the case of an automobile, to rotation of the driving shaft, and from it to the rear axle and wheels by means of the final reduction gears.

**Q. What is a torque rod?**

A. A rod, bar, or tube, provided to take, not the torque, but the equal opposite reaction from the torque application to the final drive.

**Q. What is the manifestation of this torque reaction?**

A. A tendency of the driving shaft and driving bevel gear to rotate up and around the bevel-driven gear in a counter-clockwise direction.

**Q. How does the torque rod absorb this?**

A. By extending this forward and attaching it to a frame cross-

member at the front end and to the rear axle housing at the rear end, this counter-clockwise motion of the driving shaft is prevented.

**Q. What is driving effort?**

A. The force applied to the rear wheels tending to move the car forward. It is transmitted to the car, or frame of the car, as a push.

**Q. How is this push transmitted to the frame?**

A. In one of three ways; through special radius rods which transmit it directly to the frame; through a central tube which handles both torque and driving effort, transmitting this first to a frame cross-member, then to the main side members and through the springs, which are modified in attachment so as to take care of these extra stresses.

**Q. Which is the best form?**

A. The use of radius rods, one on each side, transmitting the stresses directly to the frame, is undoubtedly the best form, but also the most expensive, the heaviest, and includes the greatest number of parts.

**Q. Which is the most simple form?**

A. The use of the springs, the so-called Hotchkiss drive, but this also reduces the easy-riding qualities of the car because the springs, which should be flexible for easy riding, must be made somewhat rigid in order to transmit torque and driving reactions.

**Q. Which is the cheapest?**

A. Undoubtedly the use of the springs is the cheapest form, as it eliminates all additional parts, and simply necessitates a pivoted form of springing end in place of the usual shackle there.

## FINAL DRIVES

**Q. What are the usual methods of final drive?**

A. Final drive is usually by one of these methods: roller chain, silent chain, spur gear, bevel gear, spiral bevel gear, worm and gear, rollers.

**Q. Are all of these in use today?**

A. All but the roller, although the two forms of chain drive have almost gone out of use for pleasure cars and are becoming less popular even for truck use.

**Q. Which is most popular?**

A. For pleasure-car use, the spiral bevel form, and for motor trucks, the worm.

**Q. Why is the spiral bevel popular on pleasure cars?**

A. Because of its many advantages. It is just as simple as the straight bevel, needs no additional parts, is more quiet, perhaps more efficient, is less likely to cut or wear, can be removed as readily, and has other minor advantages.

**Q. Why is the worm popular for trucks?**

A. It has all the needed qualities; it is efficient, silent, easy to handle, and allows bigger gear reductions than any other form. Furthermore, various gear reductions are interchangeable by changing other parts, and the worm has other advantages.

**Q. Why is the worm not used more on pleasure cars?**

A. Because it is not so well adapted to high speeds of 50 to 60 miles an hour and higher, which may be demanded, and because the large reduction between engine and rear axle, which is its biggest advantage, is not needed on pleasure cars.

**Q. What are the three mostly used forms of rear axle?**

A. The full floating, semi-floating, and three-quarter floating.

**Q. Which is the best form?**

A. From an engineering standpoint, the full floating is undoubtedly the best, but it is also the most complicated, with the largest number of parts, and the most expensive to construct.

**Q. Which is the most simple form?**

A. The semi-floating form is the most simple, but it lacks advantages which the majority of car owners want. It is the cheapest to make, but is made so through the lack of these advantages.

**Q. Which is the compromise form?**

A. The three-quarter floating form seems to offer a maximum number of advantages with the minimum of disadvantages. It has practically all the advantages of the full floating with less cost. It has all the advantages which the semi-floating lacks and costs but little more.

**Q. Which is the most popular form?**

A. The floating still has the greatest number of makers, but the three-quarter form is rapidly gaining in popularity and, in another year, will displace the full floating as the most popular, both as to the number of makers and as to the actual number of cars.

**Q. Describe the internal-gear axle?**

A. In this form a spur gear is used to drive an internal gear of larger diameter. This construction enables the separation of load carrying and power transmitting, so that one part of the axle can handle each.

**Q. For what is this used mostly?**

A. The internal-gear axle is used mainly on motor trucks, although a few heavy pleasure cars have been built with it.

**Q. What is a differential?**

A. A mechanical device for allowing the rear wheels to travel different distances when turning a curve or corner.

**Q. How is this done?**

A. By combinations, or nests, of gears and a divided rear axle, one-half being fixed to each half of the differential, with only the nests of gears connecting the two. As these are free to revolve as a unit, or stand still and have their gears revolve, the drive can either be transmitted all to one wheel, half to each wheel, or divided unequally.

**Q. What is the usual differential form?**

A. The usual differential gear is constructed with bevel or spur gears, the bevel form being more popular, the spur cheaper.

**Q. What is undesirable in present differentials?**

A. Present differentials have the disadvantage that they work for resistance not distance. This permits the wheel, which we do not want to slip, to slip on icy places so that the car cannot pull itself free, the differential making a bad matter worse.

**Q. If the differential worked correctly, how could this be?**

A. In such a case, since the differential worked only for difference in distance, and there was no difference in distance on an icy place, the power would be transmitted equally to the rear wheels. One would slip, but the other on firm ground would use its share of the power to pull the car off the icy place.

**Q. How is it expected that this result will be attained?**

A. By the use of helical gears, which, like the worm of a steering gear, are not reversible but will transmit power only in one direction.

**Q. In addition to correct differentiation, what is it expected these differentials will do?**

A. Eliminate skidding, always dangerous and always a possibility with present forms. The connection between skidding and

present differentials has never been explained, but can be readily proved by the simple process of building a car without a differential.

**Q. What forms of bearings are used in rear axles?**

A. All the different kinds of bearings are used in rear axles: plain ball, plain straight solid roller, straight flexible roller, tapered roller, a few plain bronze bearings, ball-thrust forms, and others.

**Q. Which form is most popular?**

A. There is little choice between the two forms of roller and the ball bearing. In fact, the majority of axles use several different forms of bearings; so it is difficult to compare the work of the various bearing types.

**Q. How can a broken spring clip be repaired?**

A. A good substitute for a spring clip can be made from two flat plates and four bolts to reach from one plate to the other. The purpose of the spring clip is to hold the spring to the axle; this combination will do the same thing.

**Q. How would you line up a rear axle?**

A. With a try-square and plumb bob, working downward from the main frame, determine the distance from the rear end of the frame to the back side of the rear axle, on each side of the car. If the two do not agree exactly, the axle is out of square by the difference, or by half this difference on each side. Loosen the spring bolts, set the axle correctly, tighten the bolts, and check up the measurements again.

## BRAKES

**Q. What are the two general types of brakes?**

A. The contracting-band, which is an external brake, and the internal-expanding shoe.

**Q. How are these used?**

A. There is no set rule; some designers use only the internal-expanding form, claiming this is more powerful and dependable; others use only the band, claiming this is cheaper to make and repair and just as good; still others take no side but use both forms.

**Q. Has there ever been any agreement in relation to brakes?**

A. Up to about a year ago, it was general practice to use the internal-expanding shoe brake for the emergency, or hand, brake. This was the case whether the band form was used for the foot, or running brake, or another expanding shoe.

**Q. Does this rule hold now?**

A. No. Many hand-operated brakes are of the contracting-band form, while many foot-operated forms, which would be considered the service, or running, brakes, are internal expanding. The tendency toward unit power plants is bringing back a shaft brake of the band type, operated by the hand lever.

**Q. Where are the brakes generally located?**

A. Except for the tendency just mentioned, the brakes have been located as much as possible in the rear wheels, on the assumption that this gave the most direct and thus the best application of the braking force.

**Q. How are brakes arranged on the rear wheels?**

A. When both brakes are placed on the rear wheels, practice is sharply divided into two camps. The one places the running brakes as a band form on the outside of the drum, claiming this makes a smaller lighter drum, a more compact group on the wheel, and less expensive because the drum is cheaper. The other places the two brakes side by side, making both of the internal-expanding shoe form inside a wide drum, claiming this is more effective, more powerful, and that the brakes are better protected against dirt, dust, and water because entirely enclosed, and thus are more effective and need less attention.

**Q. What is the electric brake?**

A. A new device which substitutes the rotation of an electric motor for hand or foot application of the brakes. This is put into action by a finger lever on the steering post, which makes contact, through suitable resistance, between the battery and the motor. When the motor rotates a cable is wound up and this pulls the brakes.

**Q. Is this a powerful form?**

A. Not only very powerful but also very quick to act, so that care must be used in applying it.

**Q. What is the hydraulic brake?**

A. A new form for heavy trucks and tractors, in which the use of an oil, which transmits power equally and without loss, is substituted for the usual rods and levers in the application of the brake. The construction is such that the driver can apply the brakes by a stroke of the hand lever, and if this does not give sufficient power to stop the truck, he can let the lever go forward and then pull it back-

ward again; this action soes not release the brakes but does apply more force, that is, it can be worked continuously until sufficient power is applied to stop the vehicle, a peculiarity of this particular form.

**Q. What is the vacuum brake?**

A. A new form which utilizes the suction of the engine to create a vacuum in a special braking cylinder, the movement of a piston in which applies the brake. The amount of action depends on the amount of suction, that is, regulated by the amount the valve is opened, and this is dependent upon the pressure applied to the finger lever or toe button, whichever is used.

## WHEELS

**Q. What are the usual forms of pleasure-car wheels?**

A. The plain wood form and the wire wheel comprise 99 per cent of all pleasure-car wheels; the wood forms about three-quarters and the wire about one-quarter of the total.

**Q. What are the tendencies in wheel sizes?**

A. On small cars the tendency is toward larger and larger sizes, but on the larger heavier cars the tendency is away from the very large sizes of a few years ago. The latter tendency has been brought about by the standardization of tire sizes, and the elimination of 38s, 40s, and larger sizes formerly made.

**Q. What are the different forms of wire wheels?**

A. The double-spoke form, which is lacking in lateral strength; the triple-spoke; and the quadruple-spoke. The two latter make up in strength what the former double-spoke form lacked. Except for number of spokes, these do not look any different to the casual observer.

**Q. What is the sheet-steel wheel?**

A. A form in which the whole wheel construction consists of a pair of sheet-steel members. These are given a slight taper, sometimes have holes through them for ventilation and to make them lighter, and frequently are painted to resemble wood-spoke wheels. The steel sheets are made thin enough to be flexible.

**Q. What is the pressed-steel wheel?**

A. A newer form in which a simulation of one-half the entire wheel spokes, hub and all, is pressed out of thin sheet steel, and a pair

of these welded together so that the finished product has all the appearance of a wood wheel with the usual number of spokes, but without the rim which this construction eliminates.

**Q. What are the usual truck wheel forms?**

A. Most truck wheels are of heavy wood or cast steel. The latter do not weigh a great deal more than the former; because of the greater strength of the material, less of it can be used.

**Q. Which is the most popular?**

A. The wood form is still the most popular, despite its disadvantages for heavy truck use, but the steel form is gaining rapidly?

**Q. What are the advantages of steel?**

A. Greater strength, particularly to resist side stresses; better ventilation and removal of heat from the tires; more firm foundation for the tire so that it holds its shape better; and longer life at less cost.

### Tires

**Q. What are the general divisions of all tires?**

A. Pneumatic, cushion, and solid.

**Q. What is the principle of each?**

A. The pneumatic tire has an interior air bag which is pumped full of air, the tire gaining its resiliency from this. The cushion tire is so constructed as to have a central air passage or other yielding space so that it gives a cushion effect under loads. The solid tire is a solid mass of rubber, its only give being the natural yield of the rubber.

**Q. Is there a distinct field for each?**

A. Yes. Pneumatics are used only on pleasure cars and the lighter trucks or delivery wagons; cushion tires are used mostly on slow-speed electric pleasure cars and a few light trucks; solid tires are used only on the heavy trucks.

**Q. What is the big disadvantage of the pneumatic form?**

A. Its liability to puncture or blow out, or loose its air otherwise, after which the tire is useless until the fault is mended; in fact, the tires are actually in the way, and running a deflated tire only cuts it to pieces.

**Q. What are the divisions of pneumatic tires according to shape and method of holding?**

A. While there are other forms, practically all tires today are in one of two classes, the clincher or the straight side.

**Q. Describe the clincher type?**

A. This is made with a bead or hard portion at the base, which forms a projection around which the clincher rim fits. The rim has the shape of a flattened U with the ends curled in, and the beads on the tire fit into these curled ends or clinches.

**Q. What is the advantage of this?**

A. The clincher form is held firmly on the rim, while the stiffness of the bead contributes more rigidity of form and permanence of shape to the whole tire.

**Q. Describe the straight-side form.**

A. This type of tire has no bead, the fabric forming the side walls being carried straight down to form the base without additional thickness of material.

**Q. What are the advantages of this?**

A. Its simplicity and lighter weight, with greater air space are the advantages of the straight-side form. In addition, in the newly standardized rim forms, the form of rim adapted to the straight-side tire is more simple, lighter in weight, and lower in cost than any other. It has been found by experience that the holding power of the beads was unnecessary as the inflated tire could not come off the wheel whether it had a bead or not, since its diameter at the base could not be increased in any possible way sufficiently to pass over the larger size rim.

**Q. What is an oversize tire?**

A. In the standardization of tires and rims, for each even tire size, which is called a standard, there is an oversize made which will fit on the same rim without any other changes.

**Q. What is the difference between standard and oversize tires?**

A. All standard tires are made in even inches of outside diameter, and all oversize tires are made in odd inches of outside diameter, so that the rule for oversizes is this: An oversize is one inch larger in diameter and ½ inch larger in cross-section, that is, the Ford size is 30 by 3½, the oversize for this, according to the rule, is 31 by 4; an average large car size is 36 by 4½, the oversize for this is 37 by 5.

## Rims

**Q. What are the general different rim forms?**

A. Rims are generally divided into these forms: plain, which is

no longer used; clincher, which is gradually going out; quick-detachable in its various forms; and demountable rims, now almost universal.

**Q. What are the differences in these?**

A. The clincher rim is a solid form, and the tire has to be stretched to get it on or off the rim. For this reason, it has to be made with a more or less yielding base, but even at that, tire removal is very difficult. The quick-detachable form is made with a locking ring on one side to replace the solid side of the clincher, so that tires can be applied easily. The demountable rim is a form which is used in combination with the others, this being a modification of the felloe of the wheel by which the entire tire and rim are removed in case of trouble, and then are replaced by another tire and rim which have been carried for this form.

**Q. What are the advantages of this?**

A. All roadside work is eliminated. When a puncture or blowout occurs, the driver simply jacks up his wheel, takes off tire and rim, and puts on the square tire and rim—the tire being inflated—lets down his car by means of the jack and drives off. The worn, or damaged tire, is carried at the rear in place of the spare, and is mended in the convenience and comfort of the garage or left at a tire repair station for that purpose. It saves work, time, and trouble at a time when these are of the greatest value to the owner. Given demountable rims, supplied on the car by the manufacturer, the car can be operated with all these conveniences without extra tire expense.

**Q. How are demountable rims held in place on the wheels?**

A. Nearly all demountables are held by means of wedges, with separate bolts to press these into place, or else a construction in which the bolt and wedge are combined.

## TIRE REPAIRS

**Q. What is vulcanization?**

A. Vulcanization is the curing, or cooking, of raw rubber. By this curing it is more suitable for hard usage and its soft pliable character is changed without injuring its resiliency. If these were unchanged the tire would cut and would not wear.

**Q. How is this accomplished?**

A. By the application of heat in moderate quantities and in dry form. The heat is not applied directly but through metal. In the

usual tire-curing mold the central space for the tire is surrounded by metal, with a hollow annular space outside of this into which the steam, which is generally used, is introduced. The heat from this steam penetrates the metal inside and vulcanizes the tire.

**Q. Are all vulcanizers operated by steam?**

A. Practically all the larger ones are, but many of the smaller forms of the portable type burn gasoline in the heating space, others use electric resistance coils.

**Q. What is the advantage to the private owner of a vulcanizer?**

A. When a tire is cut badly, he can apply raw rubber as a patch or repair, and then vulcanize this for the double purpose of curing and of uniting it with the older part of the tire. In this way, tire life is much prolonged at little expense.

**Q. Is vulcanization profitable as a business for a repair shop?**

A. It is said to be highly profitable, after suitable equipment has been purchased and a trade built up. It is said to be a more steady and stable business than any other, for, as soon as an owner has been convinced of the value of vulcanization of tubes and casings, he will bring in all his tire repairs.

**Q. What is a sand blister?**

A. A small opening in a casing, into which sand has entered and continues to enter until the outer surface is swelled up just like a blister. If neglected, this will ruin the casing.

**Q. How should a sand blister be cared for?**

A. By the immediate removal of the sand and the cleaning of the cavity, after which it should be filled with a tire-repairing cement or tire-filling compound. The sand can be removed by cutting a small hole in the underside of the blister with a sharp penknife.

VIEW OF PEERLESS EIGHT-CYLINDER V-MOTOR, CLUTCH, AND TRANSMISSION

*Courtesy of Peerless Motor Car Company, Cleveland, Ohio*

# EXPLOSION MOTORS

## ELEMENTARY PRINCIPLES

**General Description.** The term *explosion motor* as herein used refers primarily to gasoline engines such as are used on aerial crafts, automobiles, motorcycles, motorboats, and small stationary installations. There is nothing mysterious about this form of engine, it being similar in most respects to the ordinary steam engine, except that the force which develops the power is derived not from the expansion of steam, but from the explosion of a gaseous charge consisting of a mixture of oil vapor and air.

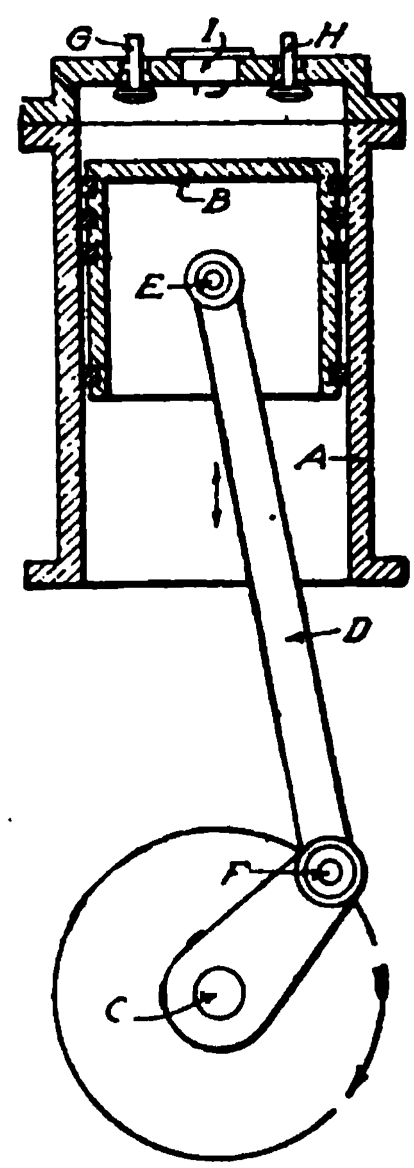


Fig. 1. Simple Explosion Motor

The simplest type of motor, Fig. 1, consists primarily of a cylinder $A$ in which there is a hollow piston $B$ (free to slide up and down), a crank shaft $C$, and a rod $D$, connecting the piston through the piston pin $E$ to the crank on the shaft. As the piston moves up and down in the cylinder this reciprocating motion is converted by the operation of the connecting rod on the crank $F$ into a rotary motion, as shown by the arrow near $C$. The whole action may be compared to that of a boy on a bicycle, $D$ representing the boy's leg and $F$ the pedal. At the head of the cylinder are shown two valves, $G$ and $H$, and a spark plug $I$, whose functions are to admit the charge, explode it, and permit it to escape, by which operations and their repetition the reciprocating motion of the piston is set up and maintained. The successive explosions of the charges produce considerable heat and, therefore, in actual practice the cylinder $A$ is usually surrounded by a jacket. Water is circulated around in the space between this jacket and the cylinder, thus cooling the cylinder. Another cooling method is by air, in which case the outer wall of the

cylinder is constructed as shown in Figs. 16 and 17. In order, therefore, to secure the above action, the following mechanical devices must be provided: (1) A cylinder containing a freely moving piston, capable of being lubricated effectively; (2) a combustion chamber in whose walls are valves for the admission and exhaust of the gas, and valve seats so arranged that the joints will remain gas-tight when desired; (3) an outside, dependable means of ignition, with sparking points inside the combustion chamber; (4) a source of fuel supply, which, in the ordinary engine, must convert liquid into a vapor; and (5) a cylinder construction which will carry off the surplus heat or allow of its being carried off.

**Historical.** The first workers in this field were perhaps Huyghens, Hautefeuille, and Papin, who experimented with motors using gunpowder as a fuel in the latter part of the seventeenth century. A patent was obtained in England by John Barber, in the closing years of the eighteenth century, on a turbine using a mixture of gas or vapor and air for the fuel. A few years later Robert Street, another Englishman, built an oil engine in which the vapor was ignited by a flame at the end of the first half of the outward stroke.

From 1800 to 1854 several French and English patents were granted for internal combustion engines, most of the engines being double acting, *i.e.,* one explosion acting on one side and the next explosion acting on the other side of the piston, and some using electrical ignition. In 1858, Degrand made a big advance by compressing the mixture in the cylinder instead of in separate pumps.

**First Practical Engine.** The first commercially practical engine was developed about 1860 by Lenoir, who marketed in Paris a 1-horse-power, double-acting gas engine closely resembling a horizontal steam engine. This used what is now called jump-spark ignition and was made in sizes up to 12 horse-power. It gave considerable trouble in many cases, but the principal reason for its failure was the excessive amount of gas required, viz, 60 to 100 cubic feet of illuminating gas per brake-horse-power hour,* which was more than three times the consumption of a modern gas engine, and prevented competition with steam.

*Otto Engine.* The gas engine industry as we know it today was really started in 1861, when a young German merchant, N. A. Otto,

*Brake horse-power (b. h. p.) is the power delivered from the shaft of the engine. When delivered for one hour it is called a b.h.p.-hour.

developed an experimental engine in which admission, compression, ignition, and exhaust were accomplished in the one working cylinder. Otto failed to realize fully the great promise held out by his engine and temporarily abandoned its development.

*De Rochas' Theory.* In the year 1862 it was pointed out by a French engineer, Beau de Rochas, that in order to get high economy in a gas engine certain conditions of operation were necessary, the most important being that the explosive mixture shall be compressed to a high pressure before ignition. In order to accomplish this, he proposed that the cycle of operations should occupy four strokes or two complete revolutions of the engine and that the operation should be as follows:

(1) Suction or admission of the mixture throughout the complete forward stroke.

(2) Compression of the mixture during the whole of the return stroke, so that it finally occupies only the clearance space between the piston and cylinder head.

(3) Ignition of the charge at the end of the second stroke and expansion of the exploded mixture throughout the whole of the next forward stroke.

(4) Exhaust beginning at the end of the forward stroke and continuing throughout the whole of the last return stroke.

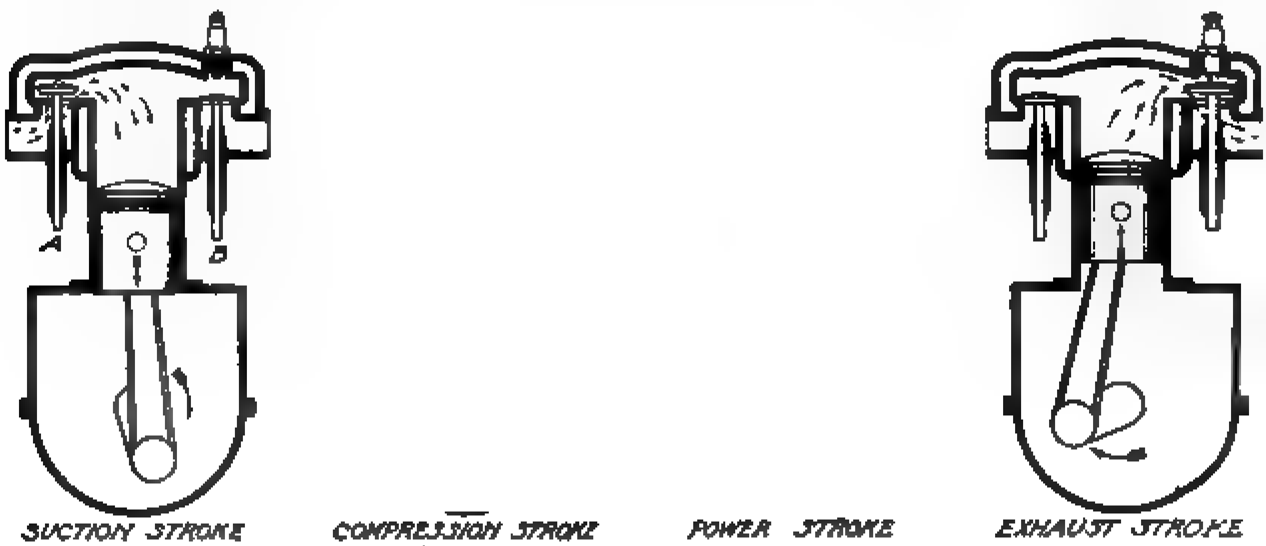
De Rochas had developed a brilliant theory but never put it into practical use. The pamphlet containing this idea remained practically unknown until about 1876, when it was discovered and published in the course of a patent-lawsuit against Otto and his associates, who were using this cycle in their engine, Otto having returned to the development of his engine in 1863. Although the original idea was perhaps Beau de Rochas', the credit really belongs to Otto, who made practical use of what would otherwise have been an unknown theory. In recognition of this fact the four-stroke cycle which Otto adopted in his engine and which is used in the majority of our modern motors is generally known as the Otto cycle.

## EXPLOSION-MOTOR CYCLE

The cycle of the explosion motor, therefore, consists of four distinct steps, viz, (1) *Admission* of the charge of explosive fuel; (2) *compression* of this charge; (3) *ignition* and *explosion* of this charge; and (4) *exhaust* or expulsion of the burned charge. If this complete process requires four strokes of the piston rod in any one cylinder, the motor is designated as a four-cycle motor, although it

would be more exact to call it a four-stroke cycle. If the complete process is accomplished in two strokes of the piston, the motor is designated as a two-cycle motor.

**Four-Stroke Cycle.** One complete operation of a single-cylinder Otto or four-cycle explosion motor is shown in Figs. 2, 3, 4, and 5. Fig. 2 shows the end of the first or suction stroke of the cycle. At the beginning of this stroke when about $\frac{1}{16}$ inch past the dead center the inlet valve *A* is opened by an eccentric rod whose movement is controlled by the eccentric on a secondary shaft driven through gears at half the speed of the motor. This allows the vapor supplied by the carbureter, which is an instrument for converting the liquid fuel




**Figs. 2, 3, 4, and 5. Diagrams Showing One Complete Cycle of a One-Cylinder Explosion Motor**

into a vapor or gas, Fig. 6, to be drawn into the cylinder by the suction produced by the downward-moving piston. During this stroke the exhaust valve *B* has remained closed.

The conditions shortly after the beginning of the second or compression stroke are shown in Fig. 3, both valves being closed. The piston, traveling as indicated by the arrows, compresses the charge to a pressure of about 60 pounds, when it is ignited at or before the end of the stroke by a spark taking place in the spark plug as shown in Fig. 4. Its arrangement is shown in detail Fig. 7, the spark passing between the points *A* and *B*. The force of the explosion drives the piston downward as shown in Fig. 4, which represents the power stroke. During these last two strokes, namely, the compression and working strokes, both valves if correctly timed should be completely closed.

Fig. 5 illustrates the conditions existing after the piston has

begun the fourth or exhaust stroke. The exhaust valve $B$ has been opened slightly before the end of the third stroke, and during this fourth stroke the gases are expelled from the cylinder through the open valve as shown. At the end of this stroke, piston and valves are again brought to the proper positions for the beginning of the suction stroke illustrated in Fig. 2.

*Compounding.* The pressure is high at the end of the expansion in the Otto cycle, and the efficiency (the ratio of work gotten out to work put in) of the cycle can be increased considerably if the gas is expanded more completely. Ordinary steam engine practice suggests that more complete expansion can be obtained by compounding. A compound steam engine has two or more cylinders. The steam or gas after doing work in the first or high-pressure cylinder completes its expansion in the other cylinder or cylinders. While the success of the compounded steam engine would lead us to expect the same increase in efficiency in the gas-engine type, no satisfactory compound gas engine has thus far been developed.

Fig. 6. Typical Modern Carbureter with Water Jacket
*Courtesy of Rayfield Carbureter Company, Chicago*

*Double-Acting.* One of the main objections urged against the Otto cycle is that it requires two revolutions of the engine for its completion, so that the expansion or power stroke comes but once in four strokes. There results from this a very irregular driving effort, making large flywheels necessary if the main shaft is to rotate uniformly, or else requiring the use of several engines working on the

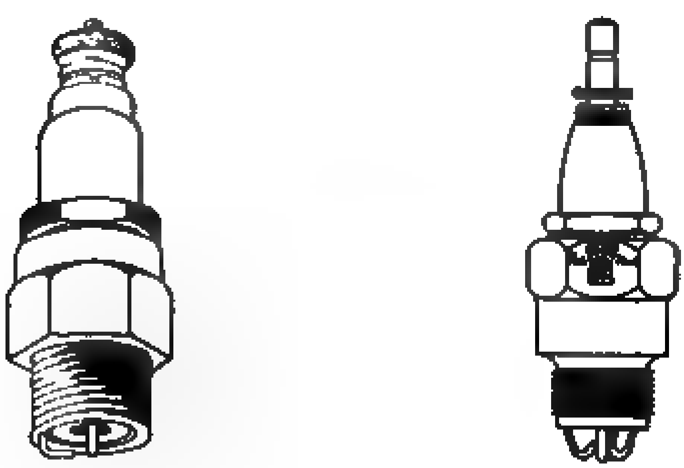


Fig. 7. Typical Forms of Spark Plug

same shaft. The power strokes can be made twice as frequent if the cylinder is double acting, with admissions and explosions occurring on both sides of the piston. Many double-acting engines are used for stationary power purposes but not for automobiles. For the latter, the irregular driving effort in single cylinders is overcome by using a large number of cylinders, as four, six, or eight, so arranged that the power impulses space out evenly.

Fig. 8. Vertical Section of Two-Cycle Smalley Motor

Fig. 9. Vertical Section at Right Angles to View in Fig. 8.

**Two-Stroke Cycle.** An increased frequency of the expansion or motive stroke can be obtained by a slight modification of the Otto cycle which results in the cycle being completed in two strokes, and which is consequently called the two-cycle method. Single-acting motors using the two-cycle method give an impulse every revolution, and consequently not only give a more uniform speed of rotation of the crank shaft, but also develop 60 to 80 per cent more power than four-cycle or Otto cycle motors of the same size. Moreover, they are generally of greater simplicity, having fewer valves than the four-

cycle motors. An example is shown in Figs. 8 and 9 of a two-cycle motor of small size and of the two-port type; Fig. 8 is a vertical section showing the piston at the bottom of its stroke, and Fig. 9 is a vertical section in a plane at right angles to the previous section plane and showing the piston at the top of its stroke. As the trunk piston *A* makes its upward stroke, it creates a partial vacuum below it in the closed crank chamber *C* and draws in the explosive charge through *B*. On the downward stroke, the charge below the piston is compressed to about 10 pounds pressure in the crank chamber *C*, the admission through *B* being controlled by an automatic valve (not shown) which closes when the pressure in *C* exceeds the atmospheric pressure. When the piston reaches the lower end of its stroke, it uncovers exhaust port *K* and at the same time brings admission port *D* in the piston opposite the by-pass opening *E*, and permits the compressed charge to enter the cylinder *G* through the automatic admission-valve *F*, as soon as the pressure in the cylinder falls below that of the compressed charge. The return of the piston shuts off the admission through *E*, and the exhaust through *K*, and compresses the charge into the clearance space. The charge is then exploded, Fig. 9, and the piston makes its down or motive stroke. Near the end of the down stroke, after the opening of the exhaust port *K*, the admission of the charge at the top of the cylinder sweeps the burned gases out, the complete escape being facilitated by the oblique form, Fig. 8, of the top of the piston. The motor is so designed that the piston on its return stroke covers the exhaust port *K* just in time to prevent the escape of any of the entering charge. The processes described above and below the piston are simultaneous, the up-stroke being accompanied by the admission below the piston and compression above it, while the down-stroke has expansion above the piston and a slight compression below it. In large engines the charge is compressed by a separate pump, and not in the crank case.

**Six-Stroke Cycle.** A recent development of somewhat problematical outcome, but apparently of much promise, is the revival of the old six-cycle idea which has been quietly undertaken by a few manufacturers.

During the earlier stages of the development of the explosion engine, we had what was termed a six-cycle or six-stroke-cycle engine, that is, one in which 6 strokes of the piston, or 3 revolutions of the

flywheel are required for each power impulse or explosion. In addition to the operations taking place in the four-cycle engine, a third revolution of the flywheel, or two strokes of the piston, were employed for admitting and expelling a charge of pure air, immediately after the exhaust stroke had been finished. By thus ridding the cylinder of the burned gases, the early workers in the explosion motor field expected to obtain more economical results in fuel consumption. These expectations were not realized and as a result the six-stroke cycle was practically abandoned until now.

The particular advantage sought by the use of this cycle is internal cooling of the motor. It is believed that the charge of cool air taken into the cylinder as a result of the addition of the two extra strokes to the ordinary four-stroke cycle will lower the temperature of the cylinder walls and piston and thus result in thoroughly adequate internal air cooling, secured at a slight sacrifice of frequency in the power stroke.

## TYPES OF EXPLOSION MOTORS

**Automobile Motors.** Automobile motors are generally vertical, multicylinder, four-cycle engines, designed to run at speeds of 800 revolutions per minute, or over, with long strokes, magneto ignition, four or more mechanically operated valves, using gasoline as a fuel, generally of the pair or *en bloc* type, and developing not more than 16 horse-power per cylinder at 1,000 revolutions. The power is usually controlled by throttling with hand and foot adjustment.

The horizontal arrangement is used sometimes with two opposed cylinders, that is, horizontal cylinders lying on opposite sides of the crank shaft and with their cranks at 180 degrees. Fig. 10 shows a chassis equipped with one of these motors.

Two-cycle engines are also used occasionally, but so far have not met with much favor in automobile practice, an exception to this, however, being the motor shown in Fig. 11. This car met unusual success, as did one other prominent machine with a two-cycle engine, but was finally abandoned in 1912 because of other plans of the new owners of the Elmore plant. The other car, the Amplex, was discontinued in 1913 through the failure of the company marketing it. This leaves the American automobile field without a two-cycle adherent, although there is one very successful American

motorcycle, the Shickel, with an engine of that form, and almost innumerable numbers of motor-boat engines of the two-cycle type still in use. On the other side, the English Valveless cars, Fig. 12, and Scott motorcycles present notable successes with the two-cycle engine.

The peculiar points of interest and the differences in design from the accepted four-cycle form are as follows: Each piston has as its base an increase in diameter containing two packing rings. This part of the piston might be called the pumping piston and forms with the enlarged lower half of the cylinder a gas pump. When gas is driven out by this pump it does not go to the upper half of the same cylinder for firing, but it goes by way of the gas

Fig. 10. Typical Horizontal-Opposed Engine for Commercial Car Chassis
*The Autocar Company, Ardmore, Pennsylvania*

distributor to the upper part of a different cylinder. This gas distributor is the two-part cylinder running the full length of the motor.

*Cylinders.* It is standard practice in automobile work to use either four or six cylinders arranged vertically in a row and usually with the cylinders cast in pairs, although the block form of casting is gaining most rapidly.

*Valves.* There are several standard arrangements of valves in automobile motors. The two valves may be (1) both on one side of the cylinder; (2) one on each side of the cylinder; (3) both in the head; or (4) one on one side of the cylinder and one in the head. When more than two valves per cylinder are used, the arrangement varies from these, of course. With three valves, as used on the

Fig. 11 Elmore Two-Cycle Valveless Motor
*Formerly Made by Elmore Manufacturing Company, Clyde, Ohio*

Fig. 12. Two-Stroke Valveless Engine
*Manufactured by David Brown and Sons, Huddersfield, England*

Franklin car at one time, there were two concentrics, in the head and one on the side. Racing motors, with four valves per cylinder, usually have all four in the head or two in the head and two in the side walls at a 90-degree angle to the axis of the cylinder.

The arrangement of an automobile motor cylinder with valves on opposite sides is shown in Fig. 13. This design requires two cam shafts, which are shown driven through an intermediate gear. Later practice uses a silent chain for this drive. The spark plugs may be over either set of valves or, with double ignition, over both.

Fig 13. Automobile Motor with Valves on Opposite Sides

When the valves are placed on top, it is necessary to use levers between the push rods and the valves with some such arrangement as that shown in Figs. 18, 19, 20, and in detail in Figs. 22 and 23. The inlet valve is here placed over the exhaust. The latter is operated directly by a push rod. The inlet is worked by a separate push rod through a rocker arm, working from a fulcrum on the cylinder head.

When both valves are overhead, a double arrangement like this is necessary or else an overhead cam shaft like that shown in

Fig. 14. This shaft is driven by bevel gears and another vertical shaft at the front end of the motor. The spark plugs are placed horizontally in the cylinder side, below the inlet manifold.

A marked departure in valve construction is that shown in Fig. 15, which is the Stearns-Knight type of sleeve valve motor. This valve action consists of two concentric sleeves sliding up and down between the piston and cylinder walls. These sleeves open and close the ports, which are side slots opening directly into the combustion

Fig. 14. Overhead Valves Driven by Overhead Cam Shaft
*Courtesy of Maudslay Motor Company, Coventry, England*

chamber. These sleeves are moved up and down by small connecting rods from a crank shaft driven by a silent chain.

A modern tendency is toward the use of more valves, one development (following racing successes) having four per cylinder.

**Marine Motors.** The principal difference between marine and automobile practice is in the much more extended use of two-cycle motors for small powers in motorboats. Where four-cycle motors are used they do not differ from automobile motors except they are generally stronger and heavier, of larger size and lower speed.

**Motorcycles.** The motor used in the motorcycle is of the ribbed, air-cooled, four-cycle, vertical type, usually single cylinder

OILING

PORT OI

C
OPERATIN

CONNECTI
OPERATING INNER

FLY WHEEL

OIL TROUGH ADJUSTING
LEVER CONNECTED
TO THROTTLE

LOWER PART OF CRANK
CONTAINING OIL
STRAINER AND

S

r

ONNECTING ROD

CHAIN DRIVE
ENTRIC SHAFT

HAIN DRIVING
T FOR ELECTRIC
OR

HAIN DRIVE
NETO SHAFT

CLUTCH

BEARING

OIL SCOOP

ADJUSTABLE OIL TROUGHS

Fig 15. Part Section of Stearns-Knight Motor Showing Sleeve Valves
*The F. B Stearns Company, Cleveland, Ohio*

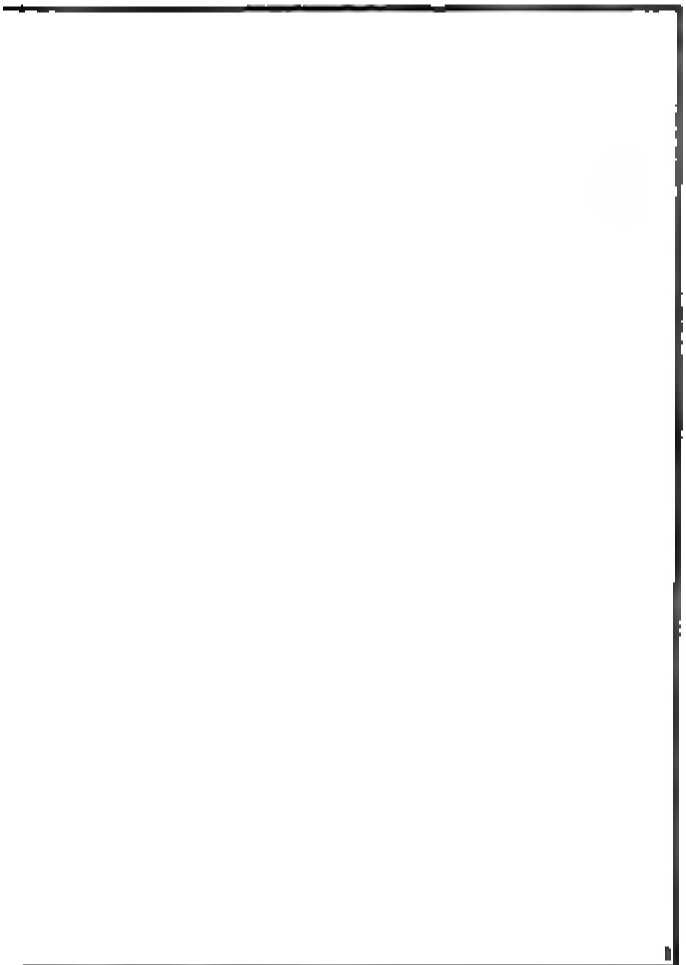


Fig. 16. Single-Cylinder Motorcycle Motor
*Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois*

or V-twin cylinder. Some of the later models, however, are showing four-cylinder motors. In Figs. 17 and 18 are shown the standard types of engines found in motorcycles.

**Aeronautical Motors.** The principal requirements of an aeromotor are greater power per pound of weight, reliability, simplicity, freedom from vibration, and fuel economy.

This field is just now receiving a great deal of attention from inventors and manufacturers. The motors are of the two-cycle or four-cycle type, either air-cooled or water-cooled, with vertical, horizontal, or revolving cylinders.

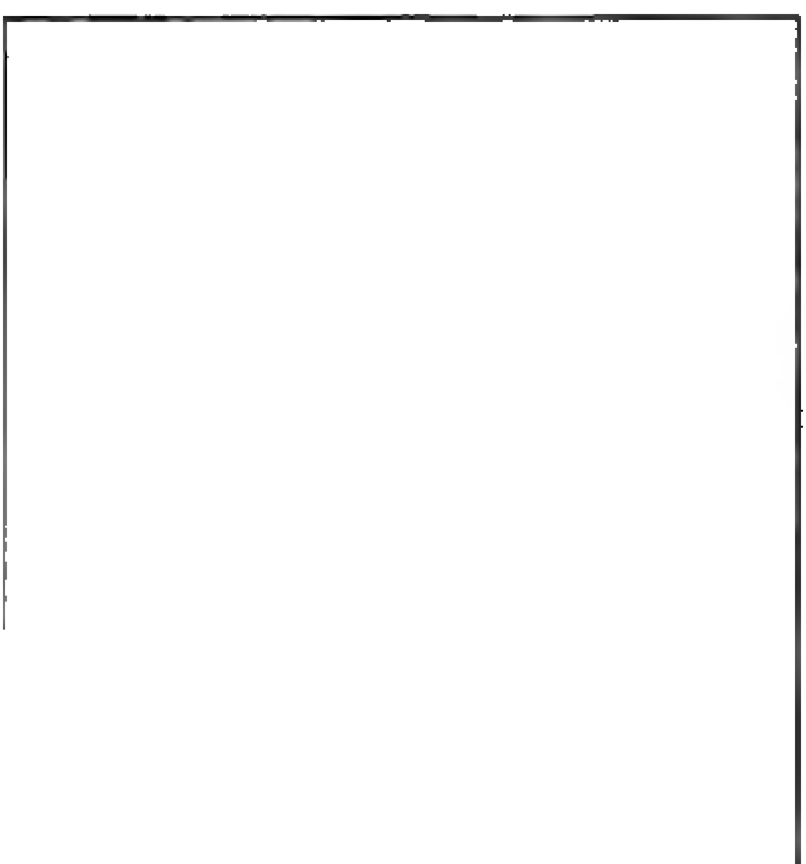


Fig. 17. Excelsior Twin Motor

The principal aim of the majority of inventors seems to have been to reduce the weight. The average weight of these motors alone without accessories is about 3½ pounds per horsepower, few exceeding 4½ pounds, the lightest one weighing only 1.8 pounds per horsepower. However, it should be understood when considering this

remarkable weight, or rather lack of weight, that most of these motors can not be depended upon for a sustained flight of more than about one hour's duration. The final developments will undoubtedly result in a somewhat heavier motor than these.

## MOTOR DETAILS

### FOUR-CYCLE TYPE

While discussions of explosion motors must deal in fundamentals, a practical study of a standard type will give the greatest benefit to

**Fig. 18. Exhaust Side of Reo Automobile Motor**
*Reo Motor Car Company, Lansing, Michigan*

the student. The motor chosen as the subject of this careful analysis of the functions of its parts and relations to the other parts is of the vertical, four-cylinder, four-cycle, water-cooled type, made by the Reo Motor Car Company. An exterior view is shown in Fig. 18, while detailed views of the motor are shown in Figs. 19 and 20.

**Valves.** In each cylinder there are two valves, viz, the inlet and the exhaust. The inlet valve, which admits the explosive mixture to the explosion chamber, is located in a case in the cylinder

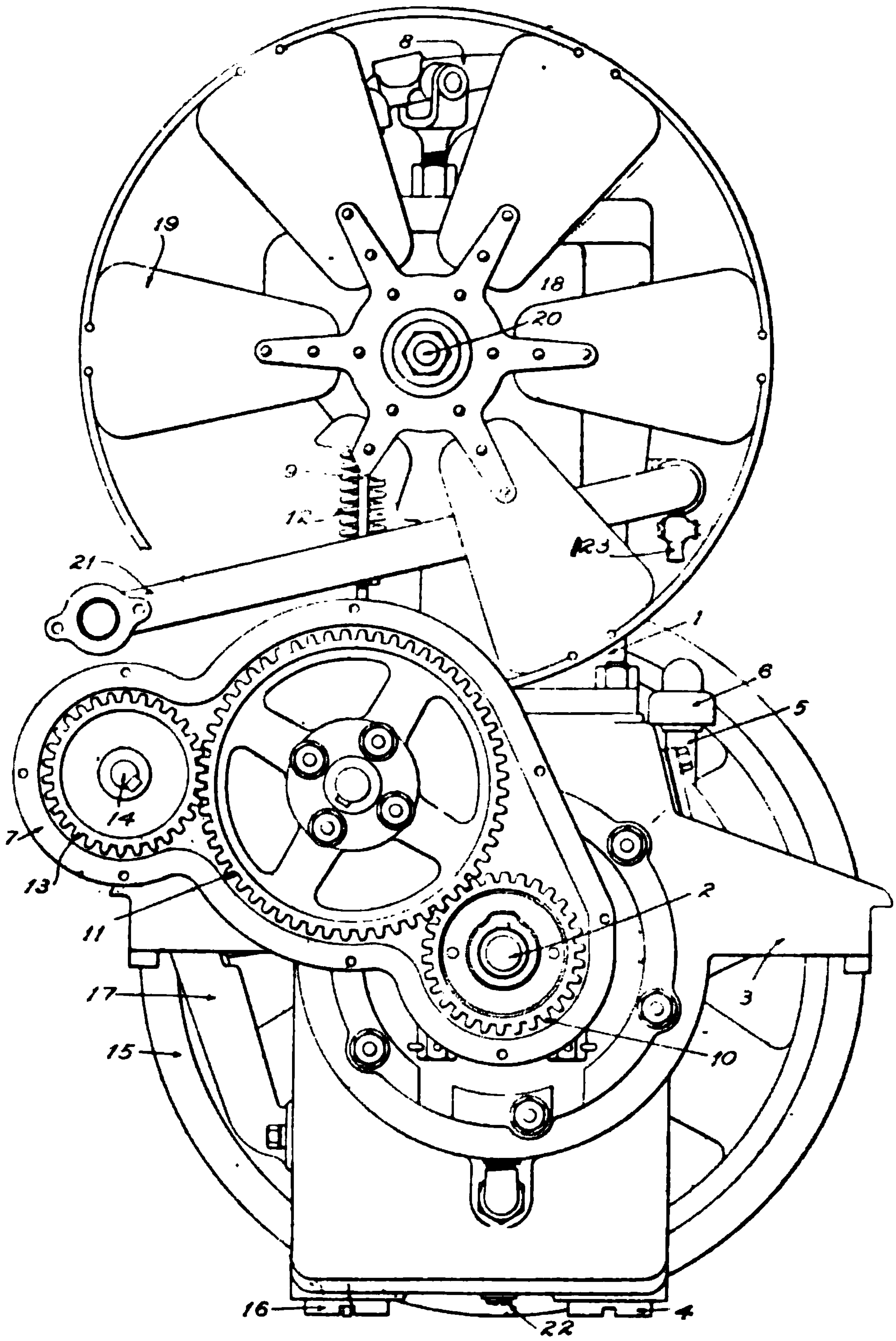



Fig. 19. End View of Typical Motor

### Index of Parts to Motor, End View, Fig. 19

1. Cylinder casting; 2. Crank shaft; 3. Crank case; 4. Plug for crank-case oil reservoir; 5. Vent pipe for crank case; 6. Cap for crank-case vent pipe; 7. Cam gear housing; 8. Inlet-valve lever; 9. Inlet-valve push rod; 10. Small cam gear; 11. Large cam gear; 12. Valve spring; 13. Drive gear for magneto and pump; 14. Drive shaft for magneto and pump; 15. Flywheel; 16. Oil-pump cylinder; 17. Oil-gauge casting; 18. Fan support; 19. Fan blades; 20. Fan shaft; 21. Water pipe, pump to cylinder; 22. Drain plug for oil reservoir; 23. Drain cock for cylinder water jacket.

Fig. 20. Part Section of Side View of Reo Motor

## Index of Parts to Motor, Side View, Fig. 20

1. Connecting-rod cap; 2. Flywheel hub and clutch inner drive gear; 3. Drive bushing, flywheel to hub; 4. Flywheel; 5. Oil-pump body; 6. Oil-pump cylinder; 7. Oil-pump plunger; 8. Eccentric for oil-pump drive; 9. Oil-pump cylinder head; 10. Oil screen, or filter; 11. Oil return pipe; 12. Circulating-pump body cover; 13. Impeller for circulating pump; 14. Body for circulating pump; 15. Large fan pulley; 16. Fan bracket; 17. Fan hub; 18. Fan blades; 19. Fan shaft; 20. Cap for fan hub; 21. Cylinder inlet water pipe, pump to cylinders; 22. Cylinder outlet water pipe, rear cylinder to tee; 23. Cylinder outlet water pipe, front cylinder to tee; 24. Cylinder outlet water pipe, tee to radiator; 25. Magneto universal, drive-shaft end; 26. Disk for magneto friction; 27. Facing for magneto friction; 28. Spring for magneto friction; 29. Water-inlet pipe for intake heater jacket; 30. Cap screw for flywheel to hub; 31. Nut for cam gear housing cover, circulating pump, cover and water connections; 32. Nut for fan gear housing, valve lifter guide clamp, rear crank shaft bearing and exhaust manifold studs; 33. Nut for center cam shaft bearing lock screw; 34. Oil hole plug in fan hub; 35. Drain plug for oil pump; 36. Drain cock for circulating pump; 37. Elbow for oil return pipe; 38. Position screw for valve lifter guide; 39. Lock screw for center cam shaft bearing; 40. Ball valve for oil pump; 41. Grease cup in flywheel for clutch outer driving member; 42. Piston; 43. Exhaust-valve cover; 44. Piston ring; 45. Compression relief cock; 46. Exhaust manifold; 47. Cylinder casting; 48 Inlet valve chamber; 49. Exhaust valve stem guide; 50. Crank shaft; 51. Crank case; 52. Rear crank shaft bearing; 53. Cam gear housing cover; 54. Oil shield between cylinders and crank case; 55. Cam gear housing; 56. Magneto drive-shaft bushing in cam gear housing; 57. Exhaust valve; 58. Valve lifter; 59. Valve lifter guide; 60. Valve lifter end; 61. Clamp for valve lifter guide; 62. Inlet valve lever; 63. Inlet valve push rod; 64. Small cam gear; 65. Center bearing for cam shaft; 66. Rear bearing for cam shaft; 67. Cam shaft; 68. Inlet cam; 69. Exhaust cam; 70. Valve spring; 71. Drive gear for magneto and circulating pump; 72. Inlet valve; 73. Connecting rod.

Fig. 21. Assembled Cam Shaft, Reo Motor

Fig. 22 Fig 23

Inlet and Exhaust Valve-Opening Mechanism

## Index of Parts, Valve-Opening Mechanism, Figs. 22 and 23

1. Inlet valve; 2. Exhaust valve; 3. Valve lifter; 4. Valve lifter guide; 5. Valve lifter end; 6. Adjusting screw for inlet valve; 7. Adjusting screw for exhaust valve; 8. Locknut for valve adjusting screw; 9. Valve lifter roller; 10. Valve lifter guide screw; 11. Inlet valve lever; 12. Roller for inlet valve lever; 13. Inlet valve lever support; 14. Inlet valve push rod: 15. Cam shaft; 16. Inlet cam; 17. Exhaust cam; 18. Valve spring

head. The exhaust valve, which is so timed as to permit of the expulsion of the burned gases at regular intervals from the cylinder, is located in a pocket at the side of each cylinder. Fig. 21 shows the assembled cam shaft, the cams of which control the opening and closing of these valves. The final angular displacement of each cam is determined by test for each individual motor. In the figure are also shown the driving gear and bearings. Figs. 22 and 23 show in detail the operating mechanism of the exhaust and inlet valve.

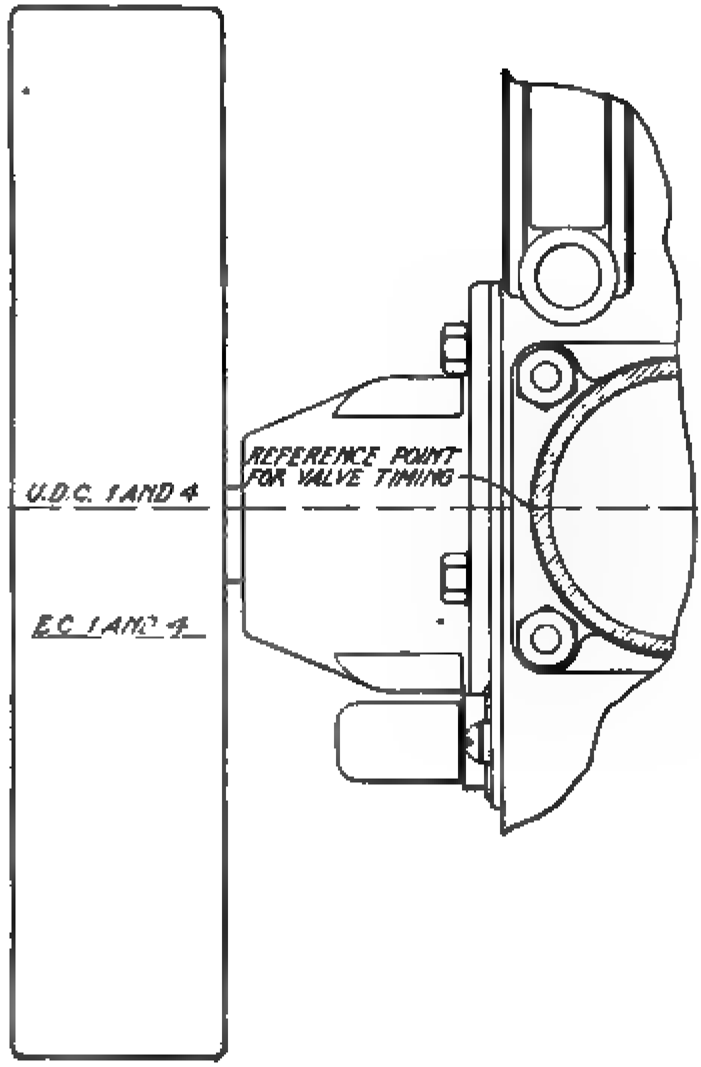



Fig. 24. Timing Data on Motor Flywheel

*Valve Timing.* In Fig. 24 is shown the flywheel,

Fig. 25. Assembled Crank Shaft

upon the face of which are the following marks: *IO*, the point at which inlet valve opens; *IC*, the point at which inlet valve closes;

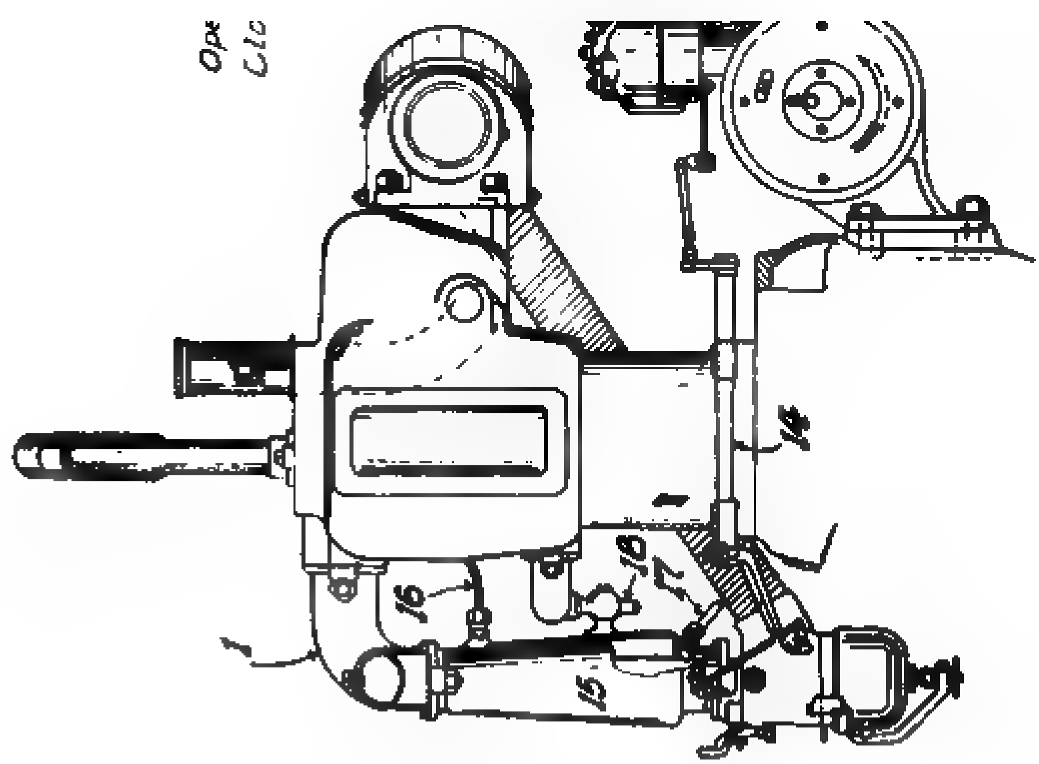



Fig 26. Diagram of Intake Manifold and Generator Attachment

**Index of Parts, Intake Manifold, Generator Attachment, and Water Pipes, Fig. 26**

1. Intake manifold; 2. Cylinder inlet water pipe cylinder to cylinder; 3. Cylinder inlet water pipe, pump to cylinders; 4. Lug on cylinder outlet water pipe for intake heater connection; 5. Cylinder outlet water pipe, rear cylinder to tee; 6. Cylinder outlet water pipe front cylinder to tee; 7. Cylinder outlet water pipe tee to radiator; 8. Generator universal drive shaft end; 9. Drive shaft for generator and pump; 10. High tension cable tube; 11. Short arm for spark control; 12. Long arm for spark control; 13. Pull rod for spark control; 14. Rocker shaft for spark control; 15. Intake pipe; 16. Water intake for intake heater jacket; 17. Water outlet pipe for intake heater jacket; 18. Drain cock for water pipe and pump; 19. Distributor; 20. Generator; 21. Pump.

Fig. 27. Wiring Diagram for Battery and Generator Ignition System

*EO*, the point at which exhaust valve opens; *EC*, the point at which exhaust valve closes; *UDC*, *1* and *4*, upper dead center for cylinders *1* and *4*; and *UDC*, *2* and *3* (not shown in figure), upper dead center for cylinders *2* and *3*.

These points are a guide as to where the inlet and exhaust valves of each cylinder should open and close. The small boss upon cylinder *4* marked with an arrow, Fig. 24, is taken as a reference point for the valve timing.

The cylinders are numbered *1*, *2*, *3*, and *4*, the first one being next to the radiator. The same markings on the flywheel that serve for cylinders *1* and *2*, also serve for cylinders *4* and *3*, respectively, since, as a glance at the crank shaft, Fig. 25, shows, these points are exactly one-half revolution or 180 degrees apart.

**Ignition.** The system of ignition used on the motor consists of a combined generator, magneto-timer and distributor shown in

diagram in Figs. 26 and 27, and in full view, Fig. 28. It is virtually a magneto system in which the permanent magnets of the ordinary magneto are replaced by electromagnets, which enables the generator to produce sufficient current for ignition, starting, and lighting. A storage battery in which to store current is a necessary part of this system. The ignition switch is located on the steering post near the dash. The spark coil is mounted on the dash underneath

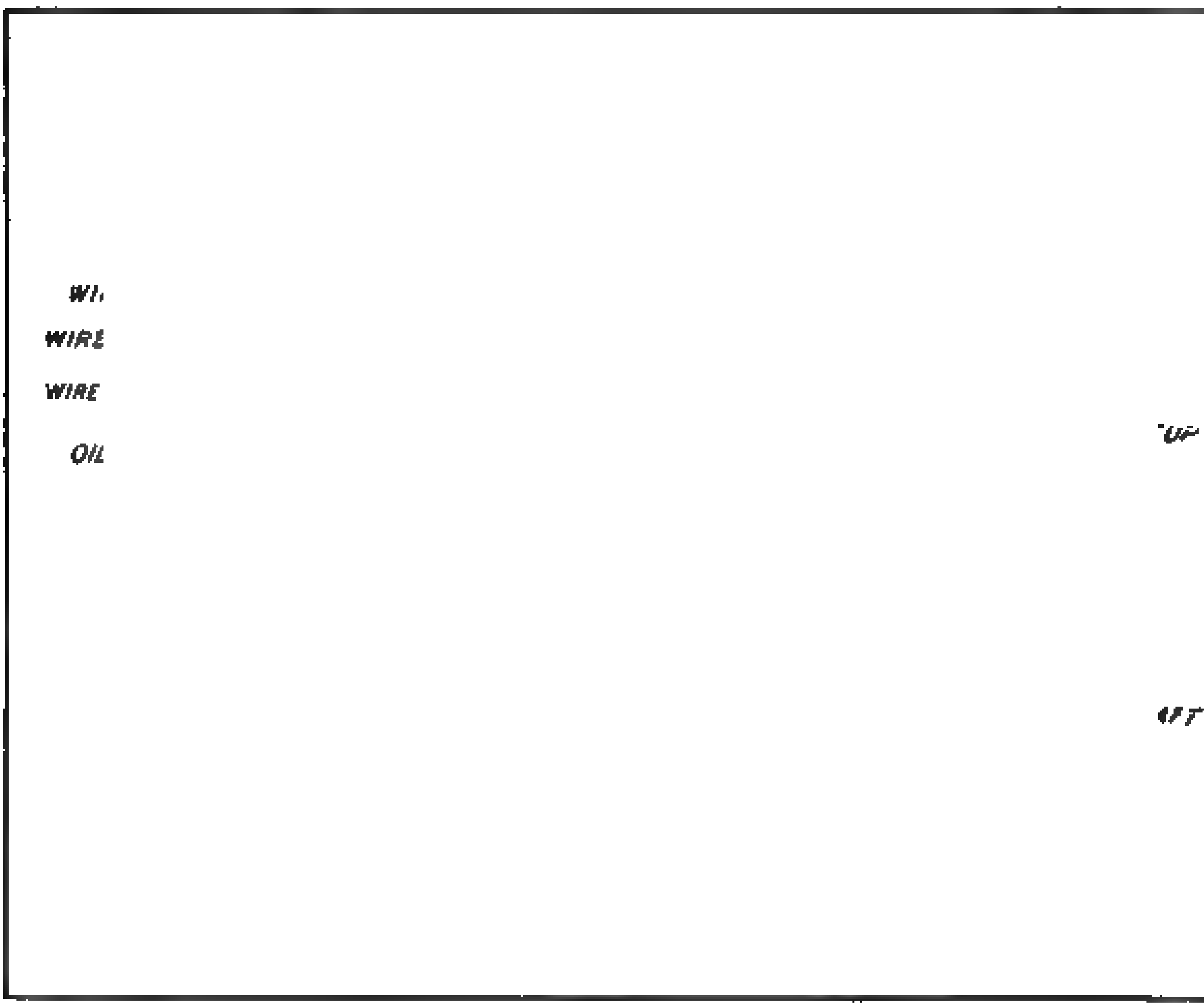



Fig. 28. Generator for Supplying Ignition, Starting, and Lighting Current
*Courtesy of Reo Motor Car Company, Lansing, Michigan*

the cowl. There is no adjustment to make in connection with the coil; a safety gap is provided for its protection on the distributor. The condenser and distributor are shown mounted on the generator, Fig. 28. This system is simply used as a type. Many other systems

**Index of Parts, Carbureter, Fig. 29**

1. Float chamber; 2. Constant air connection; 3. Spray nozzle coupling; 4. Cork float; 5. Spray nozzle; 6. Needle valve; 7. Choke throttle valve; 8. Choke throttle lever; 9. Throttle gate; 10. Throttle gate stop; 11. Gasoline pipe connection; 12 Gasoline valve; 13. Float lever; 14. Float lever studs; 15. Primer.

**Fig. 29. Johnson Carbureter**

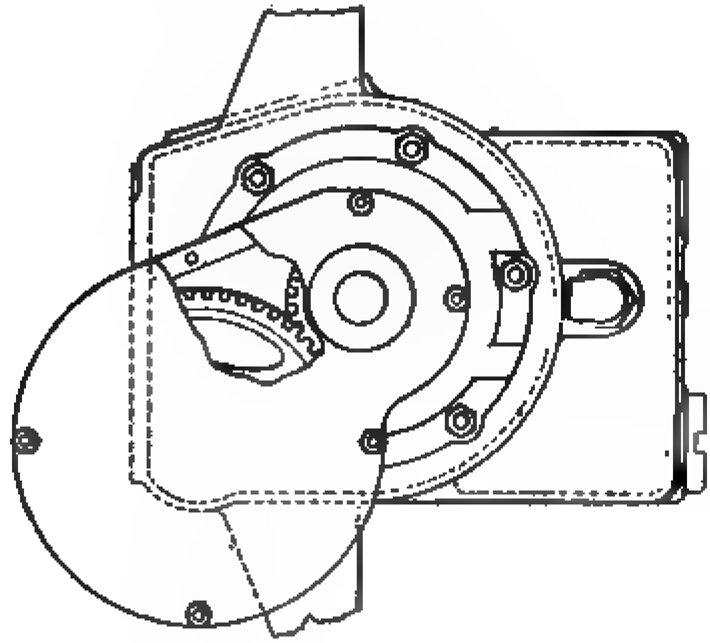


Fig. 40. Typical Oiling System on an Explosion Motor

**Index of Parts, Oiling System, Fig. 30**

1. Crank shaft; 2. Rear crank shaft bearing; 3. Cap for front and center crank shaft bearing; 4. Cam gear housing cover; 5. Cam gear housing; 6. Small cam gear; 7. Large cam gear; 8. Center cam shaft bearing; 9. Cam shaft; 10. Front cam shaft bearing; 11. Upper oil pump body; 12. Oil pump cylinder; 13. Oil pump plunger; 14. Eccentric for oil pump drive; 15. Oil pump cylinder head; 16. Oil screen or filter; 17. Tee for crank shaft oil pipe; 18. Main oil pipe for crank shaft bearings; 19. Outlet pipe for oil pump; 20. Oil pipe for center crank shaft bearing; 21. Oil return pipe; 22. Drain plug for pump; 23. Ball valve for oil pump.

are in common us
books on this subje

In Fig. 19 the
the cover remove
keyed to the cra
The large cam-sha
the cam shaft, an
tion just half as fa
magneto gear is f
pump drive shaft.
direction and at th

The carbureter, shown in detail in Fig. 29, which supplies the gasoline vapor to the intake manifold, is of the float feed automatic air-valve type.

**Motor Lubrication.** The oiling system of this motor, shown in Fig. 30, is an integral part of the motor and consists principally of a single large plunger pump driven by an eccentric from the cam shaft. The oil is forced through the pipes inside the crank case to the crank-shaft bearings and from there to the faces of the cam gears. The oil then flows

Fig. 31. Fan Details. 1 Fan Bracket; 2. Fan Hub; 3. Fan Blades. 4. Fan Shaft; 5. Hub Cap; 6. Oil-Hole Plug. 7 Ball Bearings

to the reservoirs in the bottom of the crank case where it is maintained at a constant level and from which it is picked up by scoops on the bottom of the connecting rods and distributed in a fine spray to the pistons, cylinders, and bearings.

**Cooling System.** The cooling system in a motor, *i.e.*, the system by which the cylinders are prevented from becoming too hot, con-

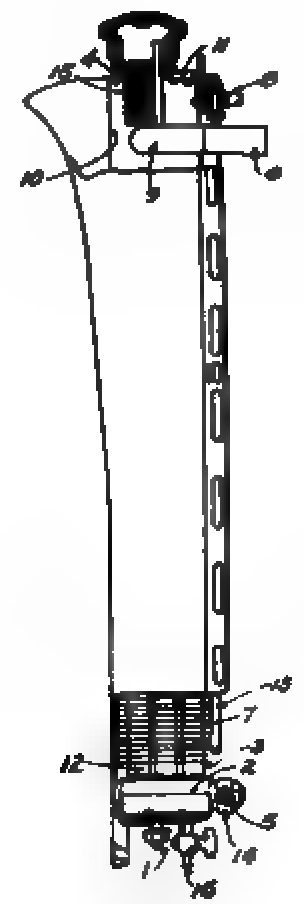


Fig. 32. Typical Radiator

sists chiefly of a *fan*, shown in detail in Fig. 31; a *pump* for supplying the cooling water, shown along with the generator drive shaft in Fig. 26; and a *radiator*, Fig. 32, which connects with the water outlet pipe and with the water pump at *13*, both shown in Fig. 20.

**Clutch.** The connection which must be established between the crank shaft of the motor and the main drive shaft running to the rear axle is made by means of a clutch, in this case of the multiple-disk type shown in detail in Fig. 33. The relation of these various parts to the rear wheels is very clearly shown in Fig. 34.

**Crank and Firing Arrangements.** The order in which the explosions should take place in the cylinders and the best arrange-

ments of cranks for multi-cylinder, four-cycle motors are shown in diagram in Fig. 35.

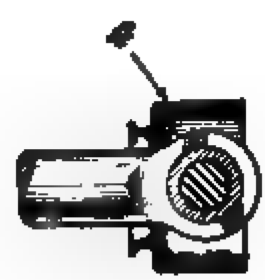
*Two-Cylinder Motor.* With the cranks set at 180°, Fig. 35A, the two cylinders fire one-half revolution apart and hence, during one revolution there are two power strokes and at the next no power stroke.

**Index of Parts, Radiator, Fig. 32**

1. Stud for fastening radiator to front cross frame; 2. Lower tank body; 3. Lower tank cover; 4. Filler pipe; 5. Outlet pipe; 6. Inlet pipe for radiator; 7. Fins for radiator; 8. Stay rod for radiator; 9 Internal intake pipe for radiator; 10. Upper radiator tank body; 11. Cover for upper radiator tank; 12 Radiator tubes; 13. Radiator overflow pipe; 14 Radiator connection for intake heater outlet pipe; 15. Screen for radiator filler pipe; 16. Drain cock for radiator.

**Index of Parts, Clutch, Fig. 33**

1. Crank shaft; 2. Flywheel hub; 3. Flywheel; 4. Block for clutch transmission universal; 5. Relief sleeve for clutch; 6. Nut for crank shaft; 7. Facing for large
:; 8. Thrust mem-
clutch; 9. Large
r clutch thrust
10. Small washer
thrust bearing;
driven gear and
fork; 12. Drive
lutch transmission



13. Bushing for
ven gear; 14. Ball
lutch thrust bear-
utch closing spring;
disk for clutch; 17.
; 18. Bearing for
Retainer for clutch
or clutch universal;
losing spring; 22.
Relief collar for clutch.

Fig. 33. Multiple-Disk Clutch

Fig 34. Complete Chassis of Reo Car, Showing How Connection Is Made Between Engine Crank Shaft, Clutch, Drive Shaft, Transmission, Differential, and Rear Axle

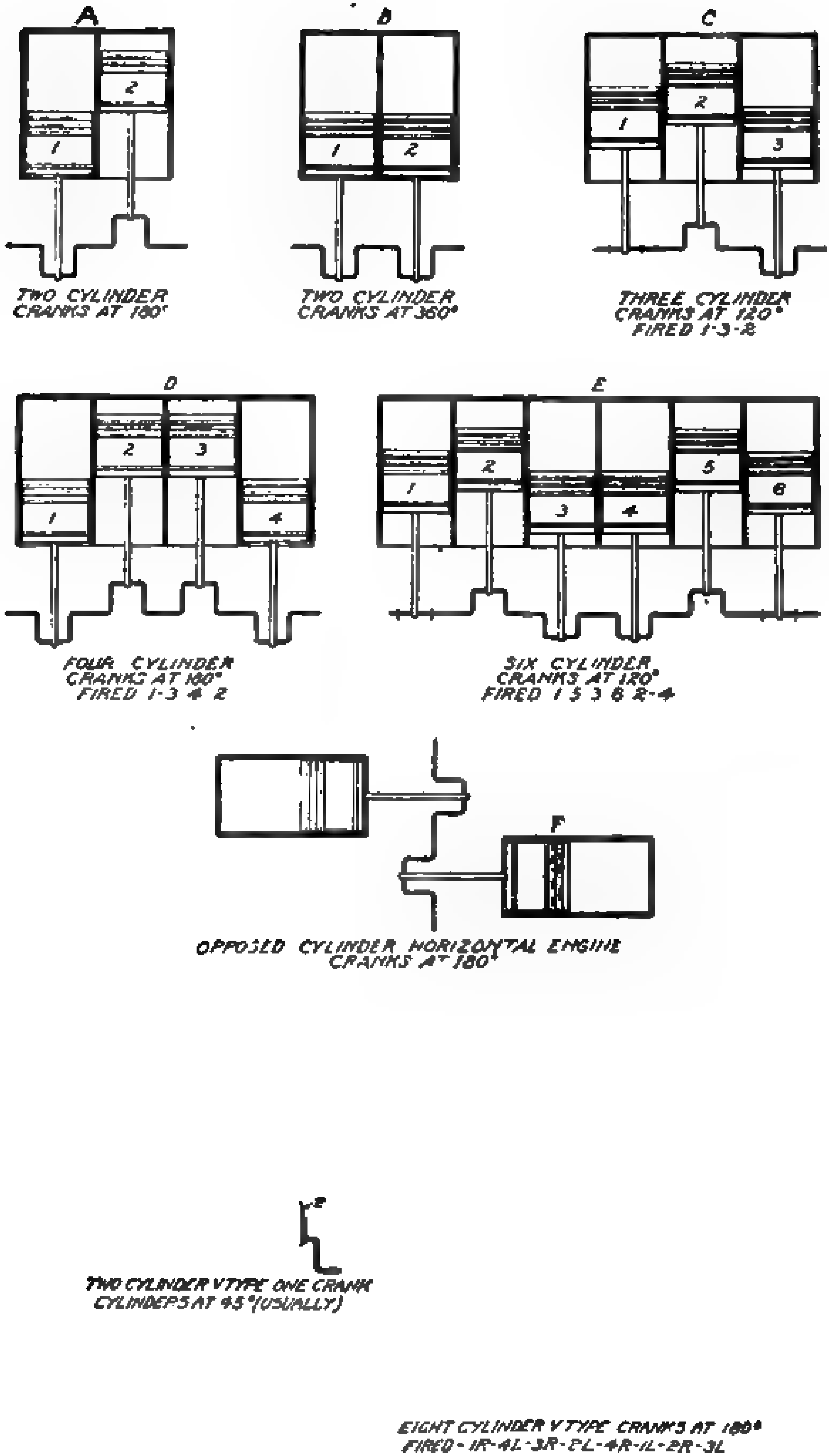



Fig. 35. Crank and Firing Arrangements for Multicylinder Four-Cycle Motors

With the cranks set at 360°, Fig. 35*B*, we get a power stroke at each revolution. This arrangement, however, requires careful balancing to counteract the vibration which results from all parts moving in the same direction at the same time. The order of action in the two cases is given as follows:

| 180° | | 360° | |
|---|---|---|---|
| First Cylinder | Second Cylinder | First Cylinder | Second Cylinder |
| Suction | Exhaust | Suction | Firing |
| Compression | Suction | Compression | Exhaust |
| Firing | Compression | Firing | Suction |
| Exhaust | Firing | Exhaust | Compression |

If the amateur finds the above difficult to follow, it may be simplified as follows: Duplicate the actions below those given, that is, repeat the action in two revolutions. Then mark off at the left the revolutions, indicating the first pair of actions for one, the second for two, etc. This applies right across the table. Then, one notes that the firing in the first cylinder comes on the second revolution and the first stroke, while that in the second cylinder comes on the same revolution but the second stroke. This gives two firing impulses on one revolution, followed by another with none, then two more firing, etc. In the cylinders set at 360°, it will be noted that the second cylinder fires on the first stroke of the first revolution, while the first follows, firing on the first stroke of the second revolution, then the second on the first of the third, and the first on the first stroke of the fourth, etc., thus distributing the firing evenly.

*Four-Cylinder Motor.* In the four-cylinder motor of the four-cycle type, we have two power strokes for each revolution of the crank shaft or flywheel. In order to secure smooth working, these power strokes should occur exactly one-half revolution apart. From Fig. 35*D* it will be seen that the four-cylinder crank shaft has two pairs of cranks just one-half revolution apart, pistons *1* and *4* moving up, while pistons *2* and *3* move down, or *vice versa.*

Suppose for instance, that piston *1* has just been forced down on the power stroke. Then pistons *2* and *3* will be up and *one* of these should be ready to receive the force of the explosion, and should have, therefore, just compressed an explosive charge in its cylinder ready to be ignited. For the sake of illustration let us choose piston *3* to make the next power stroke. Piston *3* now moves down

and pistons *1* and *4* move up. Since it is evidently impossible to have piston *1* contain an explosive charge without giving it one more up and down motion, piston *4* must make the next power stroke. This piston, therefore, moves down as a result of the explosion in cylinder *4*, and it is now necessary for piston *2* to make the next power stroke. Thus the order of firing is 1-3-4-2.

A study of Figs. 35*C*, 35*F*, and 35*E* will show the method of firing in the cases of the three-cylinder, the two-cylinder horizontal-opposed motors, and the six-cylinder, respectively. In Figs. 35*G* and 35 *H* will be found the corresponding methods for the two-cylinder and eight-cylinder V types. The last named is more difficult to follow out, but by treating it as a pair of fours which must fire first in one pair and then in the other, and considering this in conjunction with 35*D*, the scheme of arrangement will be plain. The actual order used on De Dion (French) and Cadillac motors is 1R, 4L, 3R, 2L, 4R, 1L, 2R, 3L.

Just as the firing order of the eight, or twin four, is followed through by considering it as a pair of fours, so the twelve or twin six may be considered as a pair of sixes. There is this important difference between the eight and the twelve, however; in the eight the two sets of cylinders are set at an angle of 90 degrees with each other, while in the twelve, the two "six groups" are usually set at 60 degrees. This makes a different interval in the firing; the firing order of any twelve might be 1R, 6L, 5R, 2L, 3R, 4L, 6R, 1L, 2R, 5L, 4R, 3L.

**Theory of Crank Effort.** *One-Cylinder Motor.* In a single-cylinder motor, four strokes of the piston are required to complete its cycle, *i. e.*, the suction stroke, compression stroke, power stroke, and exhaust stroke. Note that only one of these strokes, the third, makes power. Roughly speaking, power is not produced throughout even the entire part of this stroke, but only through about four-fifths of it. Hence, in a single-cylinder motor with a 5-inch stroke, the piston travel for one complets cycle will be 20 inches. In only about 4 inches of this distance is power produced. (See Figs. 36 and .37) Hence four-fifths of the total piston travel is a non-producer of power.

*Two-Cylinder Motor.* In the two-cylinder motor we have two power strokes to the cycle, as follows:

| | Inches of Power |
|---|---|
| **First Stroke** | |
| Cylinder *1* Suction | |
| Cylinder *2* Power | |
| **Second Stroke** | |
| Cylinder *1* Compression | 0 |
| Cylinder *2* Exhaust | 0 |
| **Third Stroke** | |
| Cylinder *1* Power | 4 |
| Cylinder *2* Suction | 0 |
| **Fourth Stroke** | |
| Cylinder *1* Exhaust | 0 |
| Cylinder *2* Compression | 0 |
| Total inches of piston travel representing power. . | 8 |
| Total inches of piston travel. .................... | 20 |

Hence, the motor furnishes power during only 40 per cent of the cycle.

*Four-Cylinder Motor.* With the four-cylinder motor we have one power stroke during each half revolution of the crank shaft.

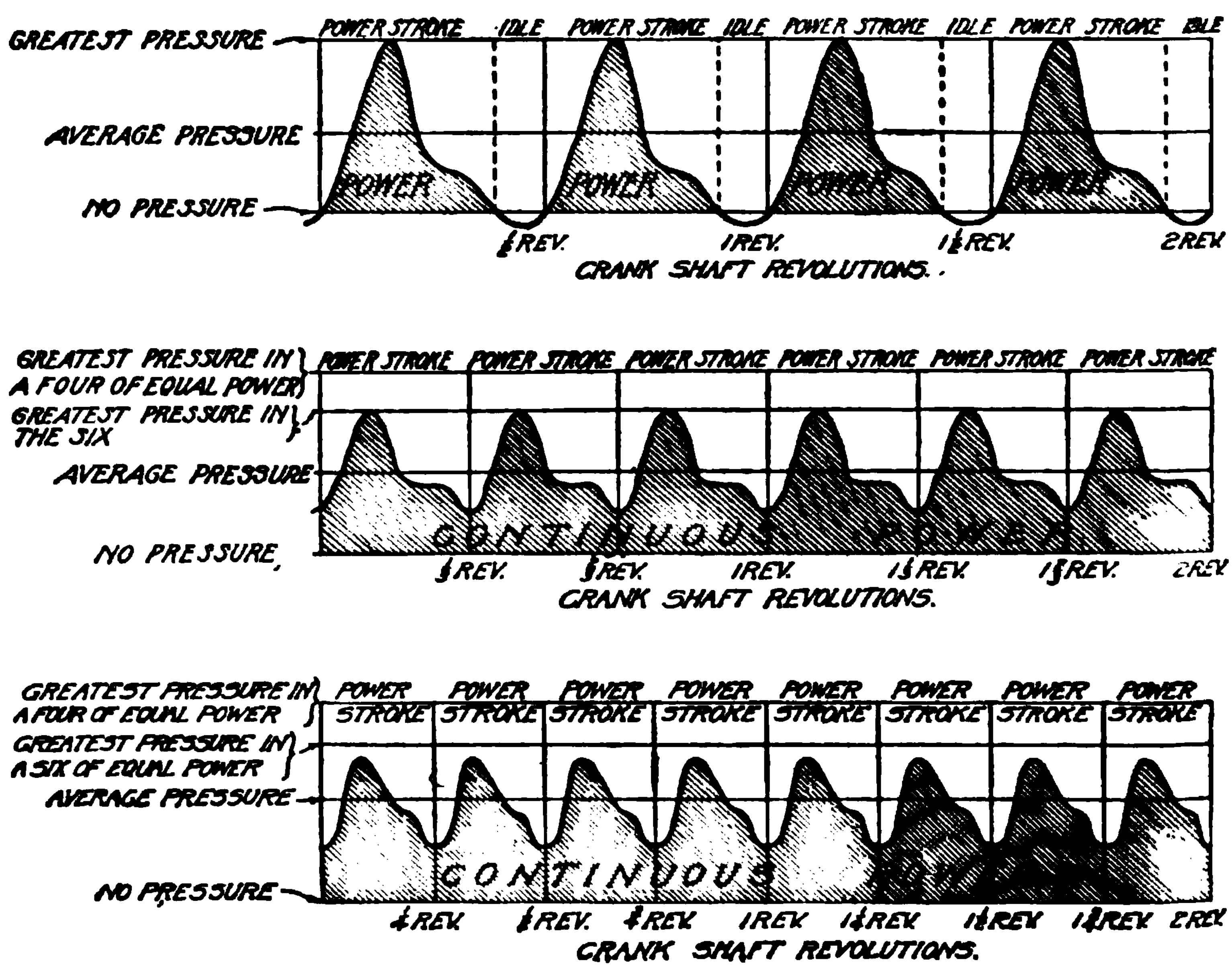



Fig. 36. Curves Showing Duration of Power in Four-, Six-, and Eight-Cylinder Motors

This gives us power during 16 inches of piston travel or power during 88 per cent of the entire cyle.

*Six-Cylinder Motor.* In the six-cylinder motor (the cylinders being the same size as those above considered, and the stroke the

same) we have 4 inches of power produced by each cylinder, making a total of 24 inches of power with a total piston travel of 20 inches. On the basis of the percentage values given in the two- and four-

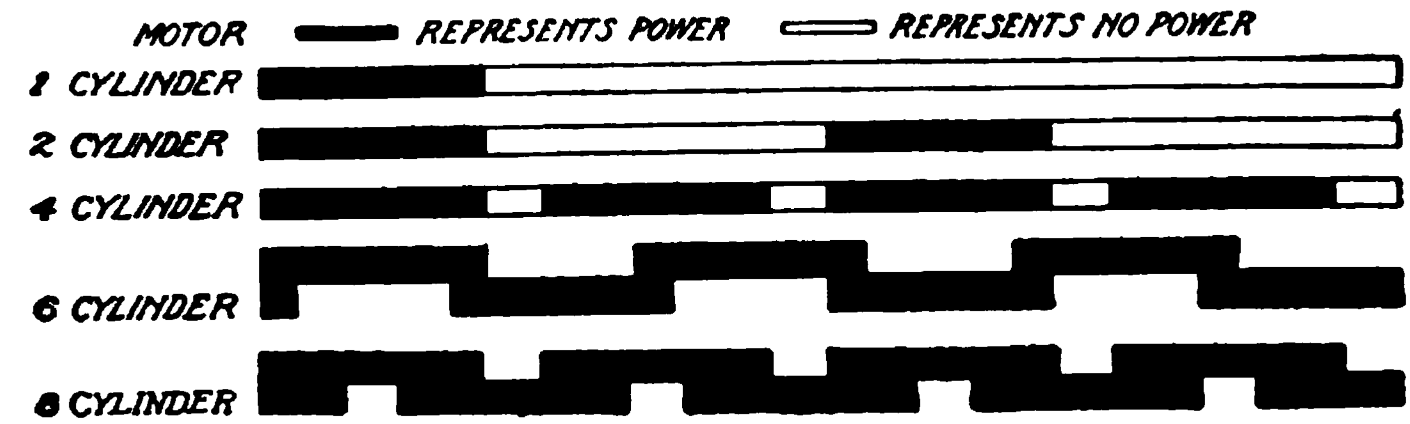


Fig. 37. Power Distribution Chart in Various Motors

cylinder types this would mean an application of power during 120 per cent of the cycle. As this is impossible and as the six cylinders are evenly spaced, the power in the cylinders must overlap each other. This results in continuous power. Diagrams showing the relation between the application of power in the four-cylinder motor, in the six-cylinder, and in the eight-cylinder, are shown in Fig. 36.

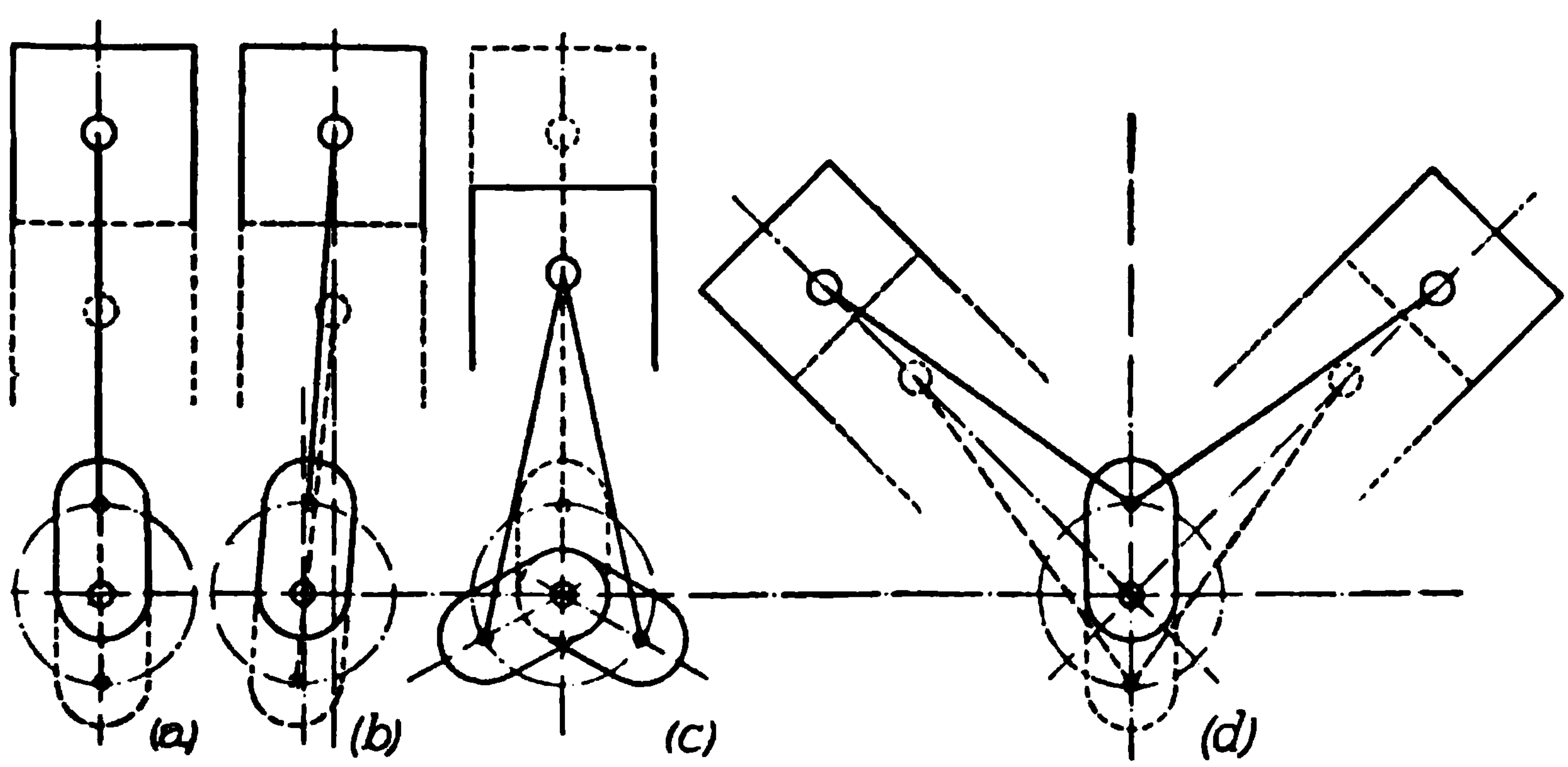


Fig. 38. Diagram of the "Dead Center" Problem

*Eight-Cylinder Motor.* In the eight-cylinder motor—the cylinders being of the same size as those considered previously, and the stroke the same—we have 4 inches of power produced by each cylinder, making a total of 32 inches of power with a total piston travel of 20 inches. On the basis of the percentage values given

for the other types, this would mean the application of power over more time in the cycle than is possible, so, as in the case of the six-cylinder motor, there is an overlap. In this instance, however. the overlap is three times as great as in the six-cylinder, consequently the delivery of power is that much more even and continuous.

*Twelve-Cylinder Motor.* In the twelve-cylinder motor, with the same size cylinders as before, we have the same 4 inches of power in each cylinder, or 48 inches total, with a total piston travel of 20 inches, showing again a large amount of overlap. Here the overlap is seven times as great as in the six-cylinder form, consequently the output of power should be that much more even.

The diagram of Fig. 37 gives a clear idea of this distribution of power in the various motors discussed except that the twelve is not shown. The difference between the twelve and the eight is approximately the same as between the eight and the six, the overlap of the power strokes for the twelve being so great as to make the white notches almost disappear.

*Effect of Dead Centers.* In both the two- and four-cylinder motors, the cranks being set 180 degrees apart, each piston is always one complete stroke ahead of the succeeding one. When the cranks of the motor are as shown in Fig. 38 (*a*) in direct line with the connecting rod, the entire motor is on dead center. Fig. 38 (*b*) shows the same condition with offset cylinders.

In the six-cylinder motor, the cranks are set at 120 degrees, Fig. 38 (*c*), and, therefore, we have no condition when the entire motor is on dead center. It is impossible to have more than two of the cranks on dead center at once. Hence, there is never a time in the six-cylinder cycle when the motor does not produce power.

In the eight-cylinder V-type motor, Fig. 39, the cranks are set 180 degrees apart, as in the four-cylinder, but the cylinders are set at 90 degrees, 45 each side of a vertical, as shown in Fig. 38 (*d*). The connection of the side by side cylinders of each pair of fours to a common crank pin—the two number one cylinders, for instance, working on the first pin, the number twos on the second, etc.—eliminates all dead centers. This is one advantage of the V-type over the straight-line type for the latter has a dead-center cylinder.

In the twelve-cylinder V-type motor, the cranks are set at 120 degrees as in the six, but the cylinders are set at 60 degrees, 30 on

each side of the vertical, the only difference from Fig. 38 (*d*) being in the angle. The crank-pin attachment in the twelve is similar to the eight, the first two cylinders working on the first crank pin, the second two on the second pin, and so on. Obviously the form of the crank and the setting of the cylinders at an angle eliminate all dead centers.

Fig. 39. Front View of Eight-Cylinder V-Type Motor
*Courtesy of Cadillac Motor Car Company, Detroit, Michigan*

**Power Exerted against the Pistons.** In a single-cylinder, 48-horse-power motor the explosion of the mixture practically results in the striking of a hammer blow against the piston of 28,800 pounds. In a four-cylinder, 48-horse-power motor each piston receives a blow only one-fourth as great, or 7,200 pounds. In a

six-cylinder, 48-horse-power motor each piston receives only 4,800 pounds. Similarly, in an eight-cylinder 48-horse-power motor each piston receives a blow of 3,600 pounds. Compared with the four-cylinder motor, this is a reduction of one-half; relative to the six-cylinder, it is a reduction of one-fourth.

So too, with the twelve-cylinder, 48-horsepower motor each piston receives a blow of only 2,400 pounds, one-half the blow exerted in the six-cylinder motor and two-thirds the blow exerted in the eight. It is this small amount of hammering which makes the mul-

**Fig. 40. Front View of Twelve-Cylinder V-Type Motor with Overhead Valves**
*Courtesy of Enger Motor Car Company, Cincinnati, Ohio*

tiple cylinder motor—in either eight- or twelve-cylinder form—much more quiet and easy running than can ever be the case with the four- or six-cylinder forms. In addition, the small size of the pistons for equal power development allows a much stiffer and stronger construction, even when a lighter metal, like aluminum or any of the various aluminum alloys, is used. The lighter reciprocating parts increase the output per cubic inch of cylinder, thus making the multiple type of motor relatively more efficient.

**Repair Man's Interest in Multiple Cylinders.** Every repair man should be well posted on eights and twelves for two reasons. In the first place, the average owner knows little about them, and as he considers that the repair man knows all about every kind of

motor, he will go to him for information at the first sign of trouble. In the second place, the repair man should be able to handle and repair these forms of motor, for the fact that they have more parts and are more complicated makes them more likely to need skilled attention. Moreover the average owner, knowing of this greater complexity of construction, will be averse to turning his eight or twelve over to any but the best repair men—skilled mechanics with a thorough working knowledge of the principles of the new motors. Any intelligent repair man with a thorough knowledge of the principles around which these new motor forms are built, and with an equally thorough and intimate knowledge of how fours and sixes are constructed, adjusted, and repaired, need have no fear to tackle any kind of engine new or old.

## SMALL GAS ENGINE

The general practice with small stationary engines differs quite radically from the standard motor practice just considered. However, as the fields of the two overlap, the discussion of the small stationary type at this point will not come amiss.

Fig. 41. Stationary Engine with Single Valve

**Two-Cycle Type.** A modification of the type of explosion motor shown in Figs. 8 and 9, which makes its construction even more simple, is the use of a single valve—an automatic valve which admits the charge to the crank case. In this engine, Fig. 41, the series of operations is precisely similar to that described for Fig. 8, the only difference being in the by-pass connection *E*, which has no valve between it and the cylinder. The exhaust is made to open a little earlier than the admission, so as to make sure that the pressure in the cylinder

shall have fallen below the pressure of the slightly compressed charge when the admission port opens. If the opening of the exhaust and admission ports were simultaneous, as in the engine just described, some of the exhaust gases would force their way through *E* to the crank case, and, being at a high temperature, would ignite the charge there. The piston is so shaped that the entering charge is directed to the top of the cylinder, forcing out the burned gases before any of the charge can escape through the exhaust port.

In place of the automatic inlet valve at *B*, there is sometimes used a revolving disk valve turning with the crank and containing a slot which registers with the crank case inlet during part or all of the up-stroke of the piston. The disk is pressed against its seat by

Fig. 42. Smalley Three-Port Two-Cycle Motor

a light spring. This arrangement controls the admission of the charge to the crank case, permitting of adjustment of the duration of admission, and consequently of the volume admitted. It sacrifices, however, the reversibility of the engine.

A further and last modification of this engine makes it entirely valveless and of the utmost simplicity. This feature is illustrated in Fig. 42. The admission of the charge is through the port *B*, which is covered and uncovered by the piston, and which consequently does not require any automatic valve. During the up-stroke of the pis-

ton, a vacuum is created in the closed crank case, till near the top of its stroke, when the admission port *B* is uncovered, and the explosive charge rushes into the crank case, filling it until the pressure there is approximately atmospheric pressure. The rest of the operations are exactly as in the engine just described, the charge being compressed in the crank casing during the down-stroke, and then

**Fig. 42. Vertical Four-Cycle Stationary Engine**
*Courtesy of Fairbanks, Morse and Company*

transferred through a port *D*, in the hollow piston, and through the port *E* in the cylinder wall, to the upper side of the piston when this latter is near the end of its down-stroke. This modification is generally known as the *three-port type* of the two-cycle motor.

**Four-Cycle Type.** Figs. 43 and 44 illustrate the details of a standard vertical four-cycle type of engine. This engine may be

equipped with a carbureter as in automobile practice, but is more often provided with a pump, Fig. 45, which introduces the fuel directly into the cylinder in the form of fine spray.

*Ignition.* In this type instead of producing ignition by means of a spark plug, the spark is usually obtained by making contact


Fig. 44. Vertical Four-Cycle Stationary Engine
*Courtesy of Fairbanks, Morse and Company*

and breaking contact between the electrodes or contact points of what is called a "make-and-break" igniter, shown in Figs. 43 and 46.

The igniter plug in Fig. 46 has been removed from the cylinder head. The movable electrode *B* is at the end of an arm which is fastened to the spindle *C*. When the interrupter lever *D*, which is loose on the spindle *C*, and is connected to it through a coiled spring, is lifted by an arm from the cam shaft of the engine, it rotates the

spindle *C* so as to bring *B* into hard contact with the stationary and thoroughly insulated electrode *A*. This completes a circuit and permits a current to flow from *A* to *B*. When ignition is desired the

Fig. 46. Igniter Plug

Fig. 45. Pump for Liquid Fuels
*Courtesy of Fairbanks, Morse and Company*

Fig. 47. Spark Coil
*Courtesy of Thordarson Electrical Manufacturing Company*

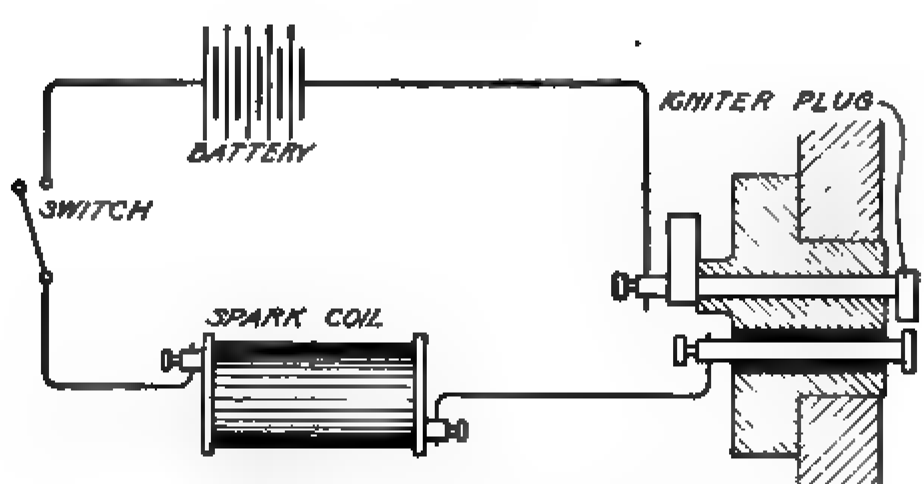



Fig. 48. Wiring Diagram for Igniter System

lever *D* is tripped and flies back, carrying with it the shaft *C*, abruptly breaking the contact and causing an electric arc to form between *A* and *B*. The spark from an ordinary battery is greatly increased

by allowing the current to flow through a make-and-break ignition coil, Fig. 47, which consists of a coil of insulated copper wire in which a laminated magnetic circuit is used in connection with an air gap. The igniter circuit is arranged as in Fig. 48.

*Governing.* Stationary engines are governed by either the "hit-and-miss" governor or the throttling governor, the latter being the form used in practically all motors. The action of the throttling governor is such that more or less fuel is admitted at each charge, according to the load, the richness of the mixture remaining the same and the engine making regular explosions. With the hit-and-miss governor, a greater or less number of fuel charges are admitted to the cylinder according to the load on the engine, the mixture and the quantity of each charge always remaining the same. The result of this is that the number of explosions per minute will vary with the load.

## THERMODYNAMICS OF THE EXPLOSION MOTOR

In explosion motors the explosive mixture in the cylinder consists of air mixed with a smaller volume of the vapor of the liquid fuel. This mixture will behave up to the time when explosion takes place, practically as if it were merely air. Also the products of combustion, after the explosion is completed, have physical properties differing only slightly from those of air, and consequently the working substance in the cylinder may without serious error be regarded as consisting entirely of air. In the discussion of what occurs in the engine cylinder, this assumption is made.

**Indicators.*** In order to more clearly understand what follows, it is necessary to have some knowledge of the indicator diagram. These are made by two forms of engine indicator, the modified steam engine form which is satisfactory up to about 500 r. p. m. and the manograph used above that speed. The former is described as consisting of a drum carrying a sheet of paper which, by rotation, is moved an amount proportional to the piston travel. An arm whose motion is governed by the pressure in the cylinder carries a pencil which traces on the paper a diagram whose vertical values are proportional at every point to the pressures in the cylinder.

---

*See also page 62.

*Watt's Diagram of Work.* James Watt was the first to see the need of accurate knowledge of the action of steam in the cylinder of a steam engine and to him belongs the credit of devising and using the first indicator. Fig. 49 illustrates the method adopted by Watt. The horizontal line *AC*, called the *abscissa*, represents the length of stroke and is divided into ten equal parts. The vertical line *AB*, called the *ordinate*, indicates the pressure of the steam.

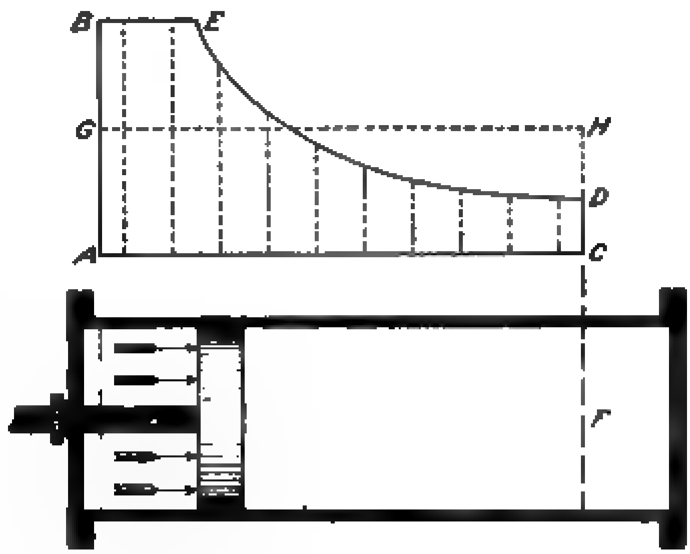



Fig. 49. Watt Ideal Diagram

Fig. 50. Crosby Indicator in Part Section

When the piston has moved from *B* to *E*, the steam is cut off, that is, a volume of steam equal to one-fifth the volume of the cylinder

Fig. 51. Crosby Indicator Complete

Fig. 52. Crosby Indicator with External Springs

is allowed to expand until it fills the entire cylinder. The area of the figure *BEDCA* may be found by adding the several pressures shown by the vertical dotted lines, dividing by the number of divisions, and multiplying by the length *AC*. The study of similar diagrams on a small scale when drawn by an indicator represents the only method of obtaining a correct idea of the action of steam in the cylinder of a steam engine or of the mixture in the cylinder of an explosion motor.

Figs. 50 and 51 show an inside and an outside view of the Crosby indicator. In gas engine work, the spring located as shown in Fig. 49 is liable to be injured by heat. To lessen the difficulties due to this, most of the makers supply indicators with external springs, as shown in Fig. 52.

**Manograph.** As has been stated previously, the steam engine form of indicator is satisfactory up to speeds of 500 r.p.m., but as the majority of gas and gasoline engine work is above that—particularly automobile and aeroplane motors in which the speed may reach a maximum of 4,000 r.p.m., while 1,000 r.p.m. would be considered a slow speed and 1,800 an average—some other form is necessary. The reason for this lies in the fact that at speeds above 500 r.p.m., the inertia of the indicator piston, pencil arm, and other moving parts is so great that the diagrams become distorted and do not show a true shape compared with the events within the cylinder. Another difficulty lies in making the passages between the cylinder and the indicator large enough so that the pressure fluctuations in the motor cylinder will be followed exactly by those in the indicator cylinder and, consequently, be reproduced exactly in the diagram.

These difficulties have led to the use of a device called the manograph. In this a beam of light travels over a visible ground glass of a darkened surface so as to be visible to the observer all of the time; or by replacing this with a sensitized piece of paper, prepared for the purpose, a print is made which must be developed and fixed the same as any photographic print. When the engine is being tested out for faults in the design and construction, the latter method is followed and the cards are preserved for future study and as a matter of permanent record. However, when the design and construction are satisfactory and the engine is simply being tuned

up to its best performance, the former method is followed and no permanent records are kept.

It can be seen at once that this is a tremendous advantage for the indicator diagram of the engine under test is visible at all times to the tester, who can increase or decrease engine speed and note at once the changes in the diagram, right in front of him; can alter carbureter or magneto settings and see at once the changes which these make in the diagram. To facilitate the use of this, it is made with as many compartments as the motor has cylinders, although all the illustrations which are shown indicate a single-cylinder outfit, which has, of course, only one compartment.

This result is obtained by the use of a small aperture through which a beam of light is admitted to the interior of the box. At one end of the latter, there is a small concave mirror, upon which the beam of light impinges. This mirror is connected to the crank shaft or other moving part of the engine in such a way that the rotation of the motor imparts to the mirror a horizontal rocking movement limited to a small angle of, say 20 degrees. This movement is, of course, at a speed which corresponds with the speed of the engine.

In addition, the mirror has a connection with the cylinders of the motor by means of which the pressures there are imparted to the mirror in a vertical direction, rocking it in that direction. The first motion—that of rotation—would make nothing but a straight horizontal line of a length proportional to the motor's stroke and at a rate proportional to its speed. But by adding the motion produced by the internal pressures, there is created a diagram or closed figure which represents accurately the events taking place within the cylinder.

*Description of Manogragh.* A general exterior view of a manograph, the Carpentier (French), is shown in Fig. 53, with horizontal and vertical sections at Figs. 54 and 55, and a detail of the mechanism which moves the mirror at Fig. 56. In Fig. 53, it will be noted that it consists primarily of a light-tight box *B*, which is generally mounted on a tripod for convenience. To one end of this is fixed a casting *A*, inside of which the mirror is secured, together with the mechanism for causing its movements. A ground-glass screen *C* is shown partially withdrawn from its position on the front of the

box, but, as has been explained, when a permanent record is desired, an ordinary photographic plate holder is substituted for this. A lamp *D* with an acetylene burner communicates with the interior by means of the tube *E* and furnishes the beam of light.

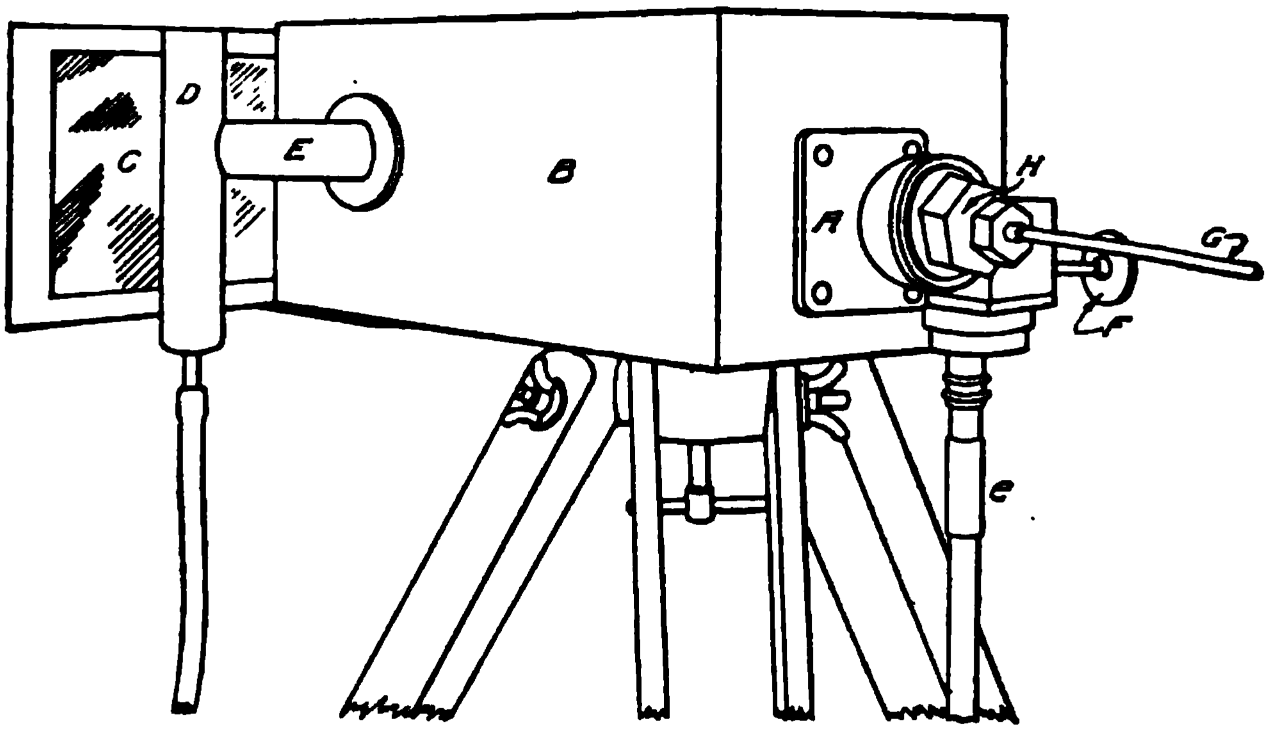



Fig. 53. General View of the Carpentier Manograph Mounted on Tripod Ready for Use

The horizontal movement of the mirror is brought about by a crank and reducing arrangement, actuated by the flexible shaft *e*. This is driven directly by the motor crank shaft, a special taper

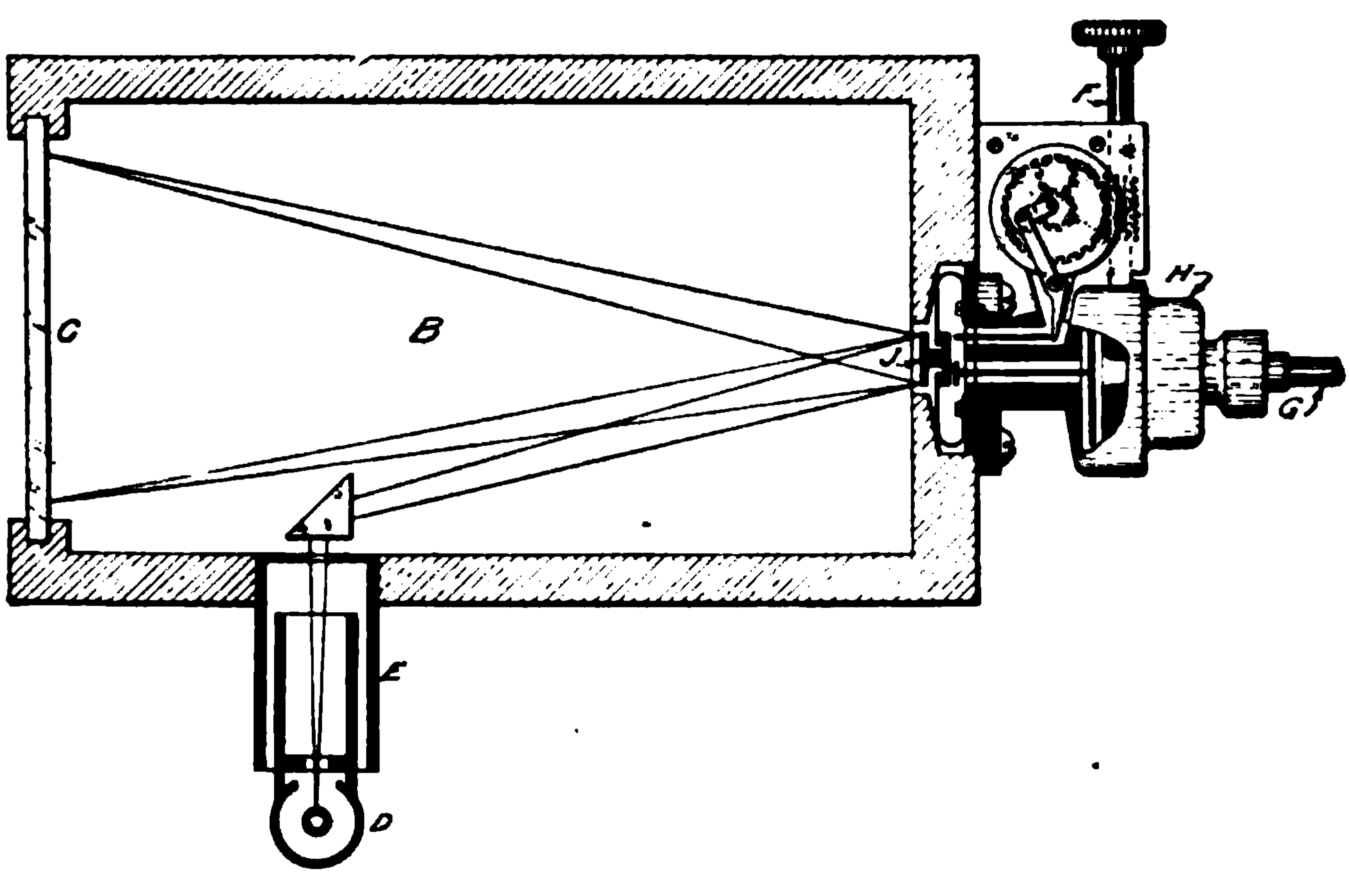



Fig. 54. Horizontal Section of Carpentier Manograph

socket being applied so that the flexible shaft may be connected or disconnected at will. In order that the motion of the beam of light and that of the piston shall correspond, an adjusting means is provided in the chamber at the right by means of the screw *F*.

The vertical movement which corresponds to the pressures in the cylinder is transmitted by means of the pipe *G*, which com-

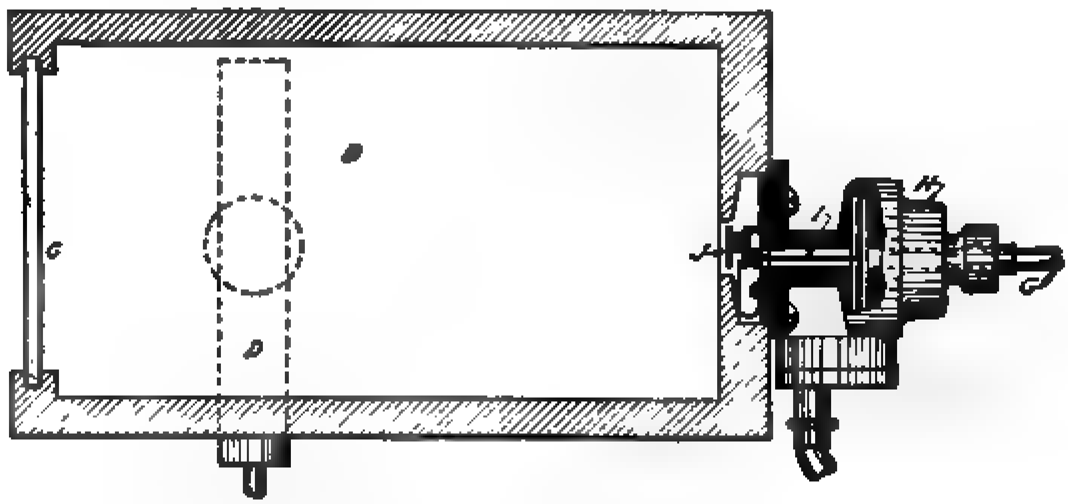


Fig. 55. Vertical Section of Carpentier Manograph, Showing Interior Arrangement

municates with a diaphragm within the nut *H*. A pin bears against the center of the diaphragm and also against the back of the mirror. This may be seen in the vertical section, Fig. 55, in which this pin is marked *I*, and the mirror inside the box is marked *J*.

Fig. 56. Detailed Section of the Diaphragm of the Hospitalier Manograph, Which Is Similar to the Carpentier

In the horizontal section, Fig. 54, the interior arrangements are shown quite clearly, the lettering being the same as in Figs.

53 and 55. Note how the beam of light from the lamp $D$ passes through the tube $E$, is deflected by the prism against the mirror $J$, and then thrown on the screen or plate $C$. Referring to the detail view, Fig. 56, $A$, $F$, $G$, $H$, $I$, and $J$ are the same as before. Gears $n$ and $m$ have an equal number of teeth, $n$ being driven by the flexible shaft $e$. It will be noted that $m$ carries a pin to which is attached a small connecting rod $l$. This is attached to the lever $k$, which is pivoted on the small screw $o$ shown about midway of its length. The far end of this lever presses against the pin $j$, which in turn rests against the triangular plate $t$, to which the mirror $J$ is held by the spring $s$.

Fig. 57 A Four-Cylinder Manograph as It Is Rigged up Ready for Use, Indicating How the Four Cards Are Visible at One Time

From this it is apparent that the engine turns the gear $n$, which rotates the gear $m$. This carries the pin around and thus reciprocates the connection $l$ and with it one end of the lever $k$. The movement of the other end of $k$ moves the pin $j$, which moves the mirror $J$. The resistance of the spring $s$ forces pin $j$ against the end of lever $k$ even when it is moving away from the pin. From the foregoing, it can be seen that the manograph is well adapted to taking diagrams from high-speed motors, for there is no limit to the speed of movement of the beam of light, while the error caused by the inertia of the few moving parts is so small as to be practically negligible.

A view of the complete manograph, rigged up for four cylinders and with the engine running, indicating the four diagrams simultaneously, is seen in Fig. 57. This gives a better idea of the device. its method of use, and very evident utility than anything which has been said on the subject. Note that the arrangement of the mirrors inside is such that the curves of each pair face each other, instead of all facing in one direction. This explains, also, the fact that some of the manograph curves, Figs. 66 to 70, face in different directions. The reader is referred forward to these diagrams, as showing just what is performed by the instrument described.

To return to the slower speed or steam engine form of indicator, this makes a neat diagram and one which represents, within its speed limits, the Otto cycle taking place within the cylinders.

## IDEAL OTTO FOUR-STROKE CYCLE

**Analysis of Ideal Diagram.** Watt's work diagram may be profitably applied to the analysis of the ideal Otto cycle by means of the indicator diagram, Fig. 58. Vertical distances along the line $AB$ represent pressures in pounds per per square inch absolute,* while horizontal distances measured along $AC$ represent piston travels or, as the cross section of the cylinder is constant, these distances may also represent cylinder volumes in cubic inches. Thus point *4* represents a pressure of 350 pounds per square inch in the explosion chamber of the cylinder when the volume in cubic inches of this chamber is $V_c$.

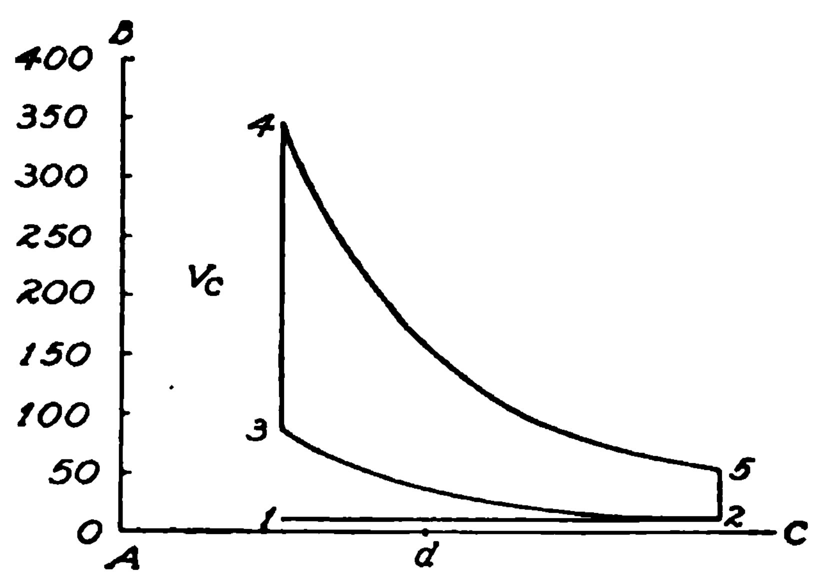



Fig. 58. Ideal Indicator Card of Otto Cycle

As the line *1-2* represents the entire piston travel, any point $d$ on $AC$ represents a certain cylinder volume or marks the position of the piston at that point in the stroke.

*Stroke One.* At the beginning of the cycle the piston is at the end of its path, point *1*, and is about to begin its out stroke, Fig. 59(a). The clearance space $V_c$ is full of products of combustion. The

*Absolute pressures are always referred to zero pressure, *i. e.*, a perfect vacuum, as a starting point. Atmospheric pressure, therefore, is 14.7 pounds absolute. *Gage* pressures on the other hand, start at atmospheric pressure, so that 80 pounds absolute would be 65.3 pounds gage pressure.

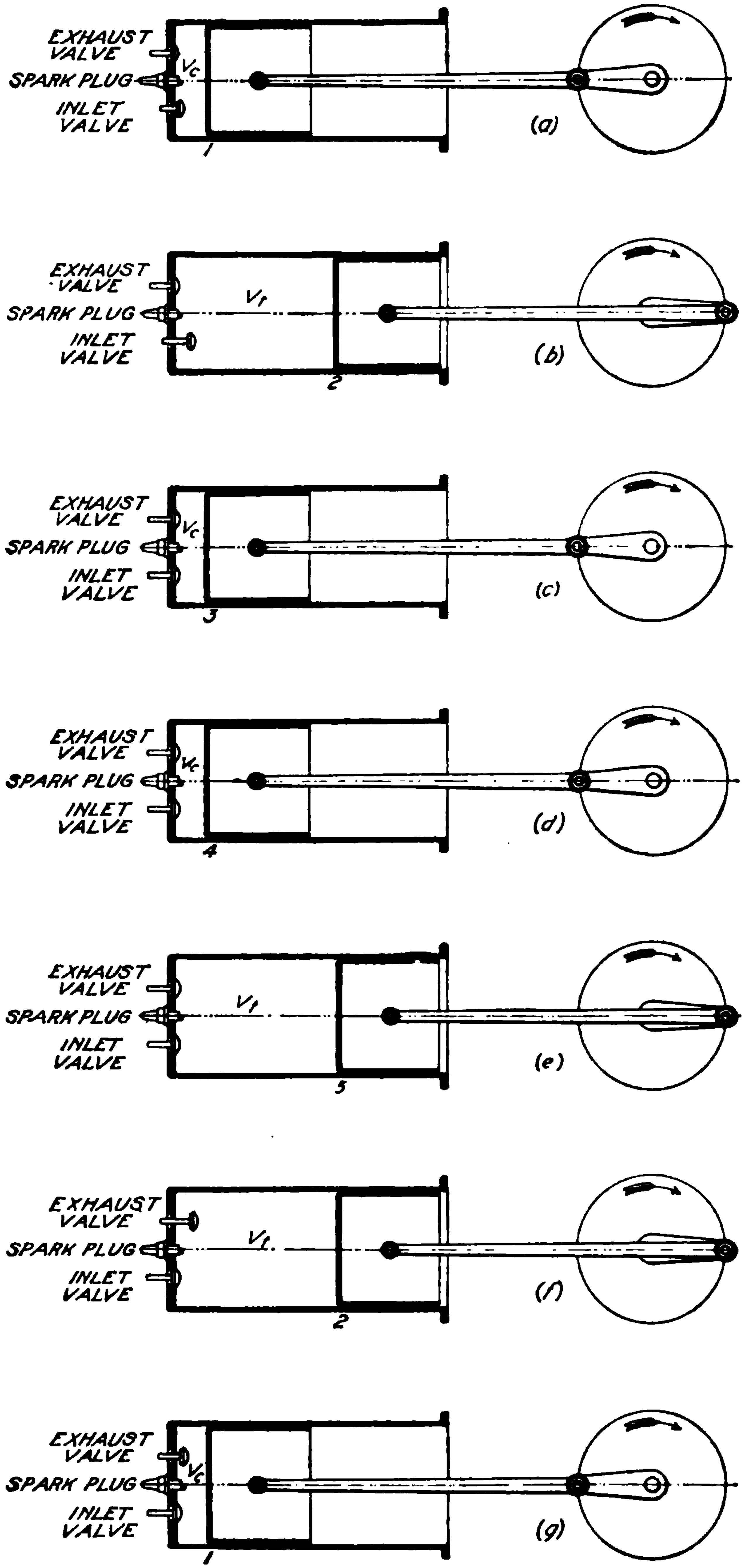



Fig. 59. Diagrams of Various Steps in an Explosion-Motor Cycle

pressure is atmospheric pressure (about 14.7 pounds per square inch) because the cylinder has been in communication with the atmosphere through the exhaust valve which has just closed. The conditions existing in the cylinder at this instant are represented in the diagram, Fig. 58, by the point *1*, which is at a horizontal distance from the vertical axis, representing the clearance volume $V_c$, also Fig. 59 (a) and at a vertical distance above the horizontal axis representing the atmospheric pressure. As the piston makes its outward stroke, the admission valve opens, admitting the charge to the cylinder throughout the stroke at atmospheric pressure. On the diagram the admission of the charge is represented by the line *1-2*, its length representing the volume of the charge taken in, or the distance through which the piston moves. The point *2* represents the condition at the end of the first stroke, the volume being $V_t$, Fig. 59 (b).

*Stroke Two.* The admission valve now closes and the piston makes its return stroke and, since all the valves are closed, the charge can not escape and is crowded into a smaller and smaller volume at increasing pressure until the piston reaches the end of its stroke, at which time the whole charge is compressed into the clearance space. This process is represented by the line *2-3*, which shows the rise in pressure resulting from the compression. At point *3* the volume is again $V_c$, Fig. 59 (c). A compression of this kind causes an increase not only in the pressure but also in the temperature of the gas, a fact often noted in the working of an ordinary bicycle pump. If it is assumed that during this compression the gas retains all of the heat formed and receives none from the outside, it is called an *adiabatic* compression. The relation between the pressure of air and its volume when subject to adiabatic compression is:

$$PV^{1.405} = \text{Constant}$$

In this equation $P$ means the absolute, not the gauge pressure.

When the charge has reached the conditions represented by the point *3*, it is ignited and the heat generated by the explosion raises the temperature and consequently the pressure of the mixture. As the volume during the explosion will not have time to change, the gas will follow the general gas law, viz, that at constant volume the pressure $P$ is proportional to the absolute temperature $T$, where absolute temperature is found by adding 461 to the temperature in

degrees Fahrenheit. The rise of pressure during the explosion is shown on the diagram by the line *3-4*, the volume of the gas being constant at $V_c$, Fig. 59 (d).

*Stroke Three.* The hot products of combustion at point *4* are at a high pressure, consequently they now force the piston out and, expanding behind it, fall in pressure. This expansion is assumed to occur without communication of heat to or from the gas and is, therefore, an adiabatic expansion. It is consequently accompanied by a fall in the temperature of the gas, the expansion curve being shown in Fig. 58 as *4-5*. This curve is similar to the compression curve *2-3* and has a similar equation.

*Stroke Four.* At the point *5* the piston is at the end of its stroke and no more expansion is possible, the volume being again $V_t$, Fig. 59 (e). The exhaust valve now opens and the pressure in the cylinder falls immediately to atmospheric pressure, as shown by the line *5-2* in the diagram, the volume remaining $V_t$, Fig. 59 (f). Throughout the last return stroke *2-1*, the exhaust valve remains open, so that the pressure in the cylinder remains atmospheric, and at point *1*, the end of the cycle, the volume is again $V_c$, Fig. 59 (g).

**Work Done by Motor.** The work done by any heat engine is equal to the difference between the heat energy that goes to the engine and that which is rejected by the engine, for whatever heat disappears can not have been destroyed and must have been converted into work. In the Otto cycle, the heat taken in is the total heat which it is possible to liberate at the explosion of each charge. In the ideal cycle no heat is rejected from the engine except during the process represented by the line *5—2* in Fig. 58, because, when the charge gets back to the condition at *2*, it has returned to its original volume and pressure and consequently to its original temperature.

**Thermal Efficiency.** The thermal efficiency of the ideal cycle is the fraction of the heat supplied that is converted into work, or when expressed in ratio form, $\frac{\text{(heat input)—(heat rejected)}}{\text{(heat input)}}$.

In the theoretically ideal cycle, the thermal efficiency is calculated to be from 40 to 50 per cent, depending upon the conditions assumed. All departures from ideal conditions result in decreasing the actual thermal efficiency of the motor. This efficiency is always less than that of the ideal cycle, usually being only from 50 to 60 per cent as great.

## OTTO FOUR-STROKE CYCLE IN PRACTICE

### General Analysis

In the discussion of the ideal Otto cycle we assumed that the compression and expansion curves were adiabatic and that the walls surrounding the combustion chamber were impermeable to heat. We also assumed perfect and instantaneous ignition, that we had a charge of uniform composition possessing all the physical properties of air, and that combustion was complete.. None of these assumptions are quite true in practice and each variation from the ideal condition has its influence upon the performance of the motor. In addition to the above, we did not consider the loss due to the necessary cooling of the cylinder. In fact, the water jacket around the cylinder (this applies to air cooling as well), without which the cylinder would be too hot to be properly lubricated, is the main cause

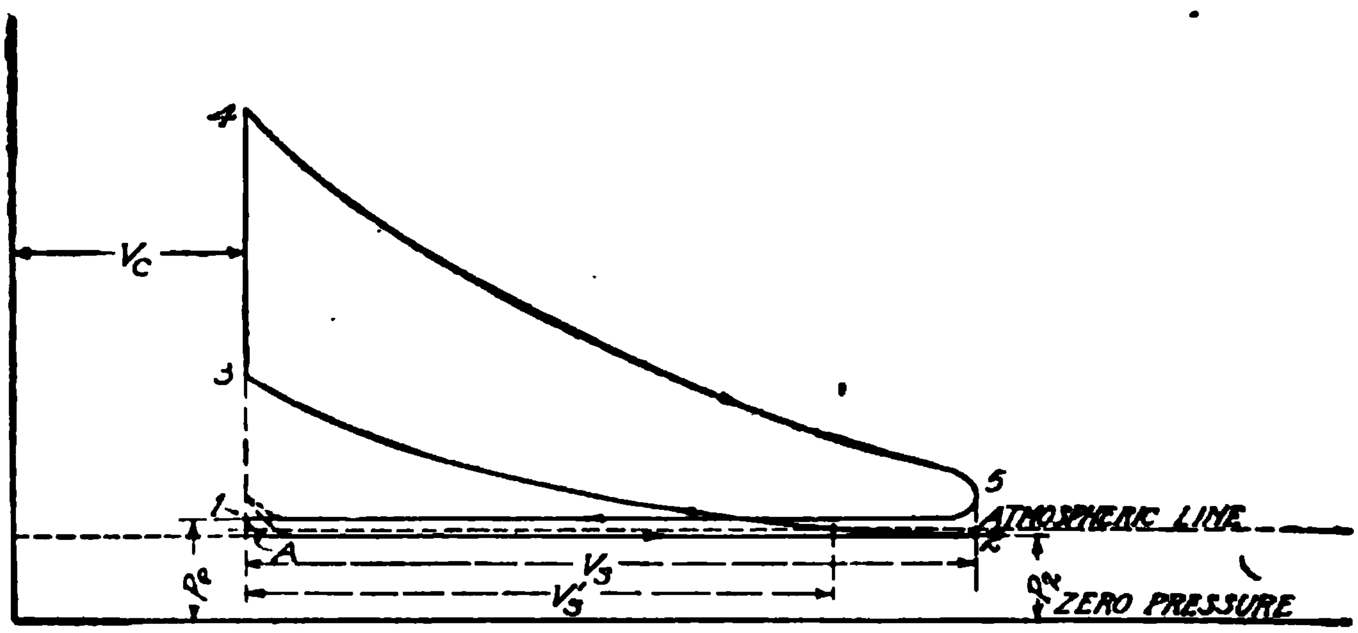



Fig. 60. Indicator Card of a Motor Following Actual Otto Cycle

of the difference between the real and ideal cycles, as the cooling agent absorbs about 40 per cent of the total heat of combustion.

In order to analyze the differences between the ideal and the actual or practical cycles, let us compare Fig. 58 with Figs. 60 and 61, which represent, respectively, the cards of a motor which is supposed to follow the actual Otto cycle, and of a four-cycle gasoline engine as found in practice.

**Suction Stroke.** At the end of the exhaust stroke, the clearance volume $V_c$, Fig. 60, is filled with burned gases at a pressure $P_e$ and temperature $T_e$. Nothing definite is known of the temperature $T_e$, except that it varies from 1,200 to 1,800 degrees Fahrenheit, while $P_e$ ranges from 16 to 18 pounds absolute pressure per square inch. At the beginning of the suction stroke the pressure decreases

from $P_e$ to the suction pressure $P_2$ along the curve determined by the re-expansion of the burned gases in the clearance space. This is the curve shown at *A*. The fresh charge can not be drawn into the cylinder until after this re-expansion of the burned gases. Anything—such as a badly formed exhaust port, restricted exhaust passage, or a too early closure of the exhaust valve—which may give us too high an exhaust pressure or too large a volume of exhaust gases remaining behind, will decrease the cylinder capacity and

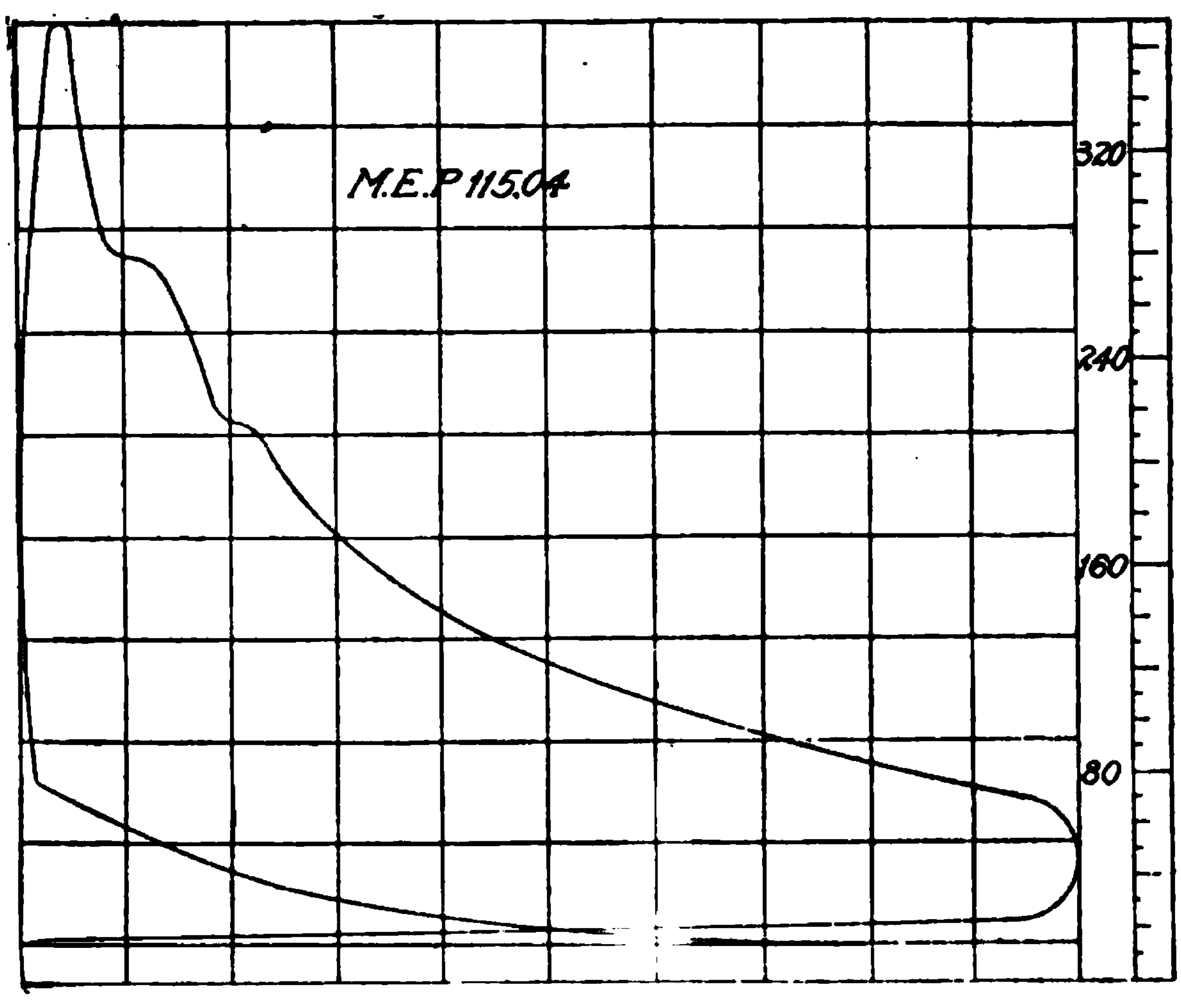



Fig. 61. Indicator Card of Four-Cycle Explosion Motor

hence materially reduce the efficiency of the cycle. The dotted line curves near *A* show how the above would affect the card.

*Scavenging.* If by any means we can reduce the effect of the clearance exhaust, we would increase the efficiency. This is actually accomplished by what is termed *scavenging.* Since the exhaust gases which occupy the clearance space are usually at a high temperature $T_e$, their mixture with the entering charge heats it, decreasing its density and, therefore, its amount. Consequently, it is very essential that these exhaust gases be excluded from the cylinder before the fresh charge enters. This clearing-out or scavenging of the cylinder with fresh air has been accomplished in several ways. The simplest method is by the use of an exhaust pipe of such length that the gases, exhausting from the cylinder with great velocity,

create a vacuum in the cylinder near the end of the exhaust stroke. This vacuum causes the automatic air-admission valve to open; and the consequent rush of air from the air-valve to the exhaust port flushes out the cylinder, especially if the air and exhaust valves are on opposite sides of the clearance space. Scavenging may also be accomplished by pumping air through the clearance space.

*Suction Pressure.* Another factor affecting the efficiency is the suction pressure $P_2$, Fig. 60. Owing to friction losses in the admission valves and pipes through which the fuel enters, the admission pressure is less than atmospheric pressure, $12\frac{1}{2}$ pounds per square inch absolute being the average value for $P_2$ in this type of motor. Owing to this reduction in pressure, the charge, if it were brought to atmospheric pressure, would occupy a volume $V'_s$ instead of $V_s$, Fig. 60. This reduction in the amount of the charge, of course, decreases the pressure developed at the end of the compression stroke and, therefore, reduces the heat developed by the explosion, which reduces the power developed within a given size of motor. Hence, the smaller the suction pressure, the less power we get, and the closer $P_2$ is kept to atmospheric pressure the greater will be the possible power output. We thus see that modifications occur at each end of the suction line which tend to decrease the efficiency of the cycle. This effect produced by the reduction of $P_2$ permits the motor to be governed by means of a throttle valve. $P_2$ is increased or decreased as required by the use of a control valve whose suction responds to the load on the engine, thus controlling the charge volume and hence the engine capacity.

The temperature $t_2$ of the charge has been found by experiment to be between 200 and 300 degrees Fahrenheit.

**Compression Stroke.** The compression is not adiabatic because it occurs in a cast-iron cylinder, which takes heat from the gas while it is being compressed and so makes the final temperature and pressure less than those calculated on the assumption of adiabatic compression. In general, however, the compression curve may be considered in actual practice to follow the general gas law. During the first part of the stroke the charge receives heat from the walls, but due to the heat generated by compression, this is soon overbalanced and during the last and greater part of the stroke the charge loses heat to the walls. As a result of this the compression curve is

found to be between an adiabatic and an isothermal.* As a result of this exchange of heat, first *from* the walls and then *to* them, the exponent $n$ in the general gas law equation $P V^n = \text{Constant}$ is not constant along the entire curve. In actual practice $n$ is found to average about 1.35. We thus have in the actual cycle, $P_3 = 12.5 \dfrac{(1+c)^{1.35}}{c}$ instead of $P_3 = 14.7 \dfrac{(1+c)^{1.405}}{c}$ for the ideal cycle, where $c$ is the percentage of clearance. (See page 58 and Table I.) The less effective the cooling, the greater will be the value of $n$. Any leaks past the piston or in the valves will result in a flattened compression curve which results in a decrease in the value of $n$.

Theoretically an increase in compression pressure $P_3$ will give an increase in efficiency. Practically this is true only up to a certain point.

The amount of compression that can be used is limited in two ways. First, it is not commercially practicable to construct motors which will work properly under very high pressures rapidly imposed by explosion. With an engine compressing a charge to 100 pounds and using a strong explosive mixture, the pressure in the cylinder rises suddenly to about 350 pounds and this is at present about the practical limit. If the explosive mixture is very weak, the compression may be increased as high as 200 pounds, resulting in a maximum pressure of about 300 pounds.

The second objection to the use of high compression is that the rise in temperature of the mixture resulting from the compression may easily be sufficient to explode the mixture before the piston has reached the end of its stroke. Such pre-ignition of the charge tends to force the piston back, giving rise to a great shock, which is not only very destructive to the engine but reduces its efficiency and consequently should be avoided. Pre-ignition may occur even with low compression, if any part of the clearance is not water jacketed, or properly air-cooled, or if there is any metallic projection in the clearance space. Lucke states that compression pressures of from

*Adiabatic compression, as already stated, is one in which all the heat resulting from the compression is retained in the gas compressed; in an isothermal compression, the heat is removed as rapidly as it is produced. In this case some of the resultant heat is retained and some of it is lost; therefore, the curve partakes of the properties of both adiabatic and isothermal lines and is found to lie between the two.

TABLE I

Effects of Clearance

| Percentage Clearance of Otto Cycle Engine | Pressure at End of Compression Lbs. per Sq. In. | Efficiency of Otto Cycle | Efficiency of Cycle with Increased Expansion, but with Same Compression Pressure as Otto Cycle. |
|---|---|---|---|
| 20 | 183.3 | 51.6 | 60.9 |
| 25 | 141.1 | 47.9 | 58.4 |
| 30 | 115.4 | 44.8 | 55.0 |
| 35 | 98.0 | 42.1 | 52.5 |
| 40 | 85.5 | 39.8 | 50.4 |

45 to 95 pounds per square inch are safe as regards the danger of pre-ignition in the type of motor under consideration.

*Effects of Clearance.* The efficiency of an engine depends not at all upon the temperature and the pressure at the end of the explosion, but only upon the ratio of the temperatures at the beginning and at the end of the compression. Since this ratio in turn depends only upon the ratio of compression, and since, further, the charge is always compressed till it occupies the clearance volume, the efficiency is seen to depend only upon the percentage of clearance. In other words, in engines using the same gas and following the Otto cycle, with the same percentage clearance, the percentage of the heat liberated in the cylinder that is converted into work is always the same, whatever be the size of the engine or the strength of the charge. The effect of the clearance on the efficiency is exhibited in Table I, where it is seen that the smaller the clearance the greater is the efficiency of the engine. The pressures at the end of compression are also given in the table, and are calculated on the assumption that the atmospheric pressure is 14.7 pounds per square inch absolute.

**Explosion.** The shape taken on the indicator diagram by the line representing the explosion of the charge depends mainly upon the inter-relation of three things, viz, the particular composition of the charge, the ignition point, and the piston speed.

For each power of engine there is a certain relation between the proportions of air and vapor in the mixture which will give the

most rapid combustion. Any increase in the amount of air or burned gases contained in the charge will result in a lowering of the rate of combustion until a point is reached where the mixture will no longer

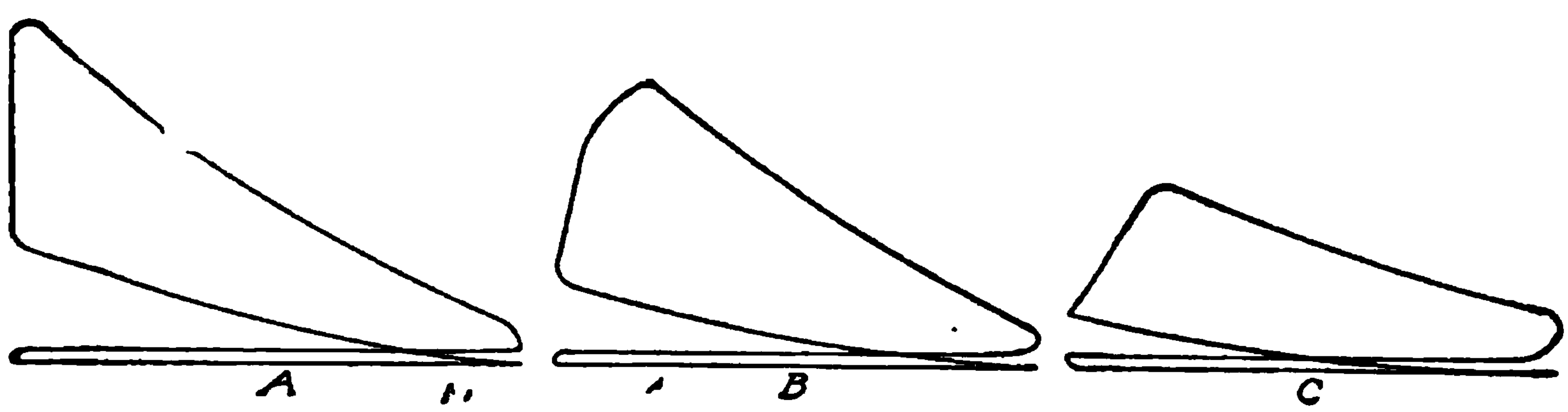



Fig. 62. Cards Showing Varying Rates of Combustion

explode. In Fig. 62, *A* is a diagram of a motor with throttle full open, speed constant, and proper ignition; *B* shows the conditions of the same engine after partly closing the throttle, thus increasing the proportion of burned gases contained in the charge; and *C* shows the conditions on further closing the throttle. Similar diagrams would have been obtained had the throttle been left full open and the proportion of air in the first charge considerably increased in *B* and *C*. A vertical or nearly vertical explosion line such as that in *A* indicates proper combustion. The more slanting the explosion line, the poorer the ignition. Referring to *C*, it is readily seen that the maximum pressure of the explosion does not begin to act on the piston until the piston has traveled a considerable distance out on the power stroke.

From the above, it will be seen that for each different fuel mixture and each different piston speed there will be a different point of ignition if we are to secure maximum results. This shows that it is advisable that each motor have adjustable ignition apparatus, because the only way to determine a proper time is by actual trial. Fig. 63 shows a set of diagrams given by Clerk which illustrates the results of improperly timed ignition. *A* is the normal diagram with proper ignition, while *B*, *C*, and *D* show what occurs as

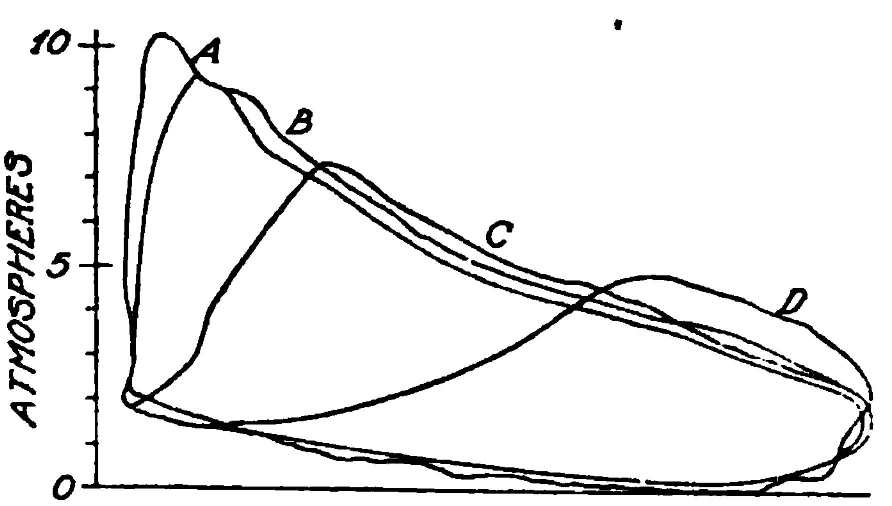



Fig. 63. Card Showing Results of Varying Time of Ignition

the ignition is made later and later. With the time of ignition remaining constant, successive increases in piston speed would have given diagrams similar to those of Fig. 63. The maximum pressure reached during combustion depends upon the heating value of the charge and should be reached at or before one-tenth stroke. The pressure ratio, $\frac{\text{maximum pressure}}{\text{compression pressure}}$, usually has a value of between 3 and 5, for gasoline.

The maximum explosion pressure (see point *4*, Fig. 60), even with proper ignition is never as high for the actual cycle as for the ideal cycle. The principal reason advanced for this is the loss of heat to the water jacket, or air, if air-cooled, this loss amounting to usually about 40 per cent of the total heat of combustion, *i. e.*, heat which results from the explosion of the charge. Some of the other

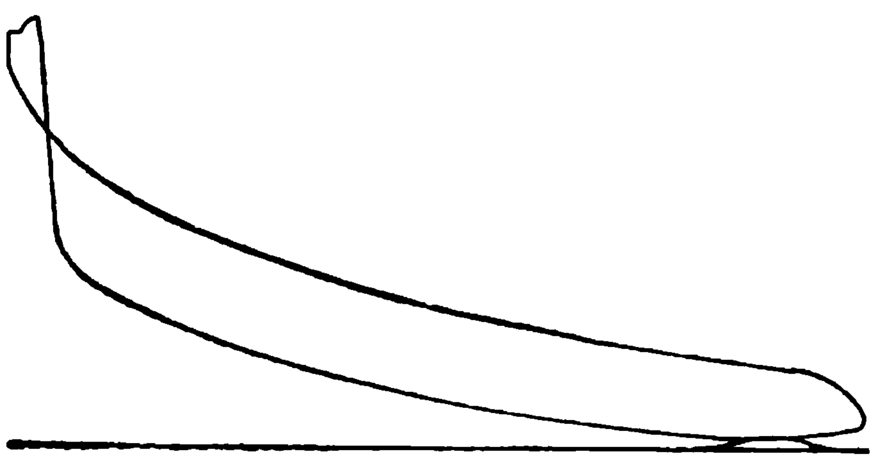


**Fig. 64.** Card Showing Result of Pre-Ignition

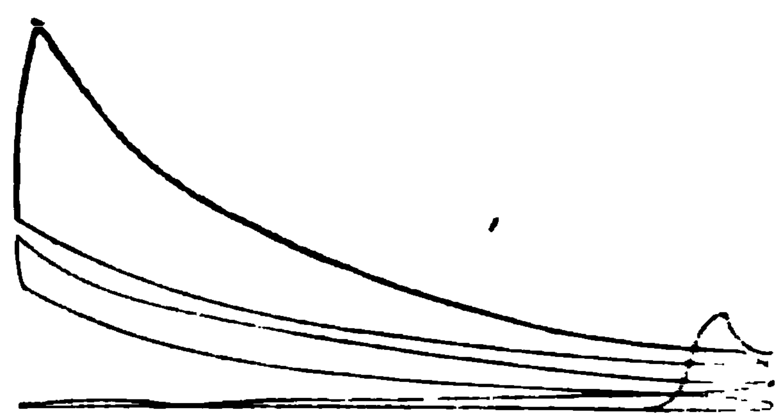


**Fig. 65.** Card Showing Case of Back-Firing

reasons are the rise in specific heat* of the gases with rise in temperature, and the fact that perhaps not all of the heat of the charge is liberated when the piston starts forward, which results in after burning.

Fig. 61 shows the card actually taken from a gasoline engine as given by Lucke. The engine had a compression of 80 pounds and a maximum pressure of 372 pounds. Fig. 64 shows the results of pre-ignition, the card clearly indicating that the explosion has occured before the end of the compression stroke and that considerable of the stored-up energy of the engine is spent in overcoming the maximum force of the explosion. This results in this particular case in cutting the power of the engine nearly in half.

*Specific heat of a substance is the ratio of the heat required to raise the temperature of a certain weight of the given substance 1° F., to that required to raise the temperature of the same weight of water from 62° to 63°F.

Fig. 65 shows the difference between a case of back-firing and the case of pre-ignition shown in Fig. 64. The explosion occurs in the suction pipe during the suction stroke. Back-firing, however, is more apt to occur in the exhaust pipe than in the suction pipe.

**Power Stroke.** The curve of expansion in the actual cycle follows the general law and, because of the loss of heat through the cylinder walls, should lie below the adiabatic curve. In practice, however, it is found that it does not fall off as quickly as expected, sometimes coinciding with the adiabatic, but usually being found between this and the isothermal. An evolution of heat along the expansion curve is supposed to be the cause of this. A great many theories have been advanced to explain this, nearly all trying to prove that, owing to certain reasons, after-burning takes place. However, up to the present time no really satisfactory explanation has been advanced. A value of 1.35 is a fair average value for $n$, thus making the general equation $PV^{1.35} = \text{Constant}$.

**Exhaust Stroke.** At the instant the exhaust begins, the velocity of efflux of the burned charge is from 2,500 to 3,500 feet per second. The exhaust valve should start to open at about one-tenth before the end of the stroke. The port should be so proportioned that the pressure has been equalized by the time the outer dead center is reached. If this is not the case there will be an increase in the work lost, due to higher back pressure, higher mean cylinder temperatures, and smaller cylinder capacity. In actual practice the pressure at the beginning of the exhaust stroke has been found in many cases to average about 25 pounds per square inch.

The movement of the burned gases out through the exhaust pipe is resisted by friction in the various parts. These gases are forced out against atmospheric pressure, hence the pressure inside the cylinder which expels them must be above atmospheric pressure. This pressure is maintained by the piston which follows up the retreating gases. The difference in pressure between that inside the cylinder and that outside, *i. e.*, the exhaust pressure and the atmospheric pressure, respectively, opposes the motion of the piston on the exhaust stroke and hence causes a loss. This loss is clearly shown in Fig 60 by the fact that the exhaust line on the indicator card is above the atmospheric line, thus decreasing the area of the card which is proportional to the amount of work done.

### Modifications for Modern Motors

**Large Valve Ports.** In modern motors, it has been found possible to modify the actual indicator card and the output of the engine very materially by slight modifications in the ports and their arrangement, as just pointed out. Thus, relative to drawing in the fresh charge of gas, after the exhausting has been nearly completed, it has been found that larger exhaust valves and ports would carry out the burned gases quicker and more completely, so as to leave a cleaner cylinder for the fresh charge to enter.

Similarly, larger inlet valves and ports have been found to give a quicker and more complete inflow of fresh charge. The two items combined—better scavenging and a more complete charge of purer gas—have had a material influence upon the efficiency. In the same way, larger intake ports and valves have operated to increase the suction pressure. As has been pointed out, this influences the pressure at the end of compression, and, therefore, the heat developed by the explosion, and ultimately the power developed. Thus, larger valves and ports producing increased suction pressure have increased the power output. This tendency has been carried up to the point where the diameter of the clear valve opening has been as close to one-half the cylinder diameter as was practicable, that is to say, a motor of four-inch bore nowadays would have valves with a clear opening of approximately $1\frac{15}{16}$-inch diameter, or just $\frac{1}{16}$ inch below half the cylinder diameter.

**Exhaust Gas Friction.** Also the exhaust gas friction produced by the pipes has been made an almost negligible quantity by making the pipes of much larger diameter, with fewer and easier bends, while larger mufflers of better design have tended to give a greater vacuum. With all these influences at work, it has been found possible to increase the speed of exhaust gases. Several recent motor designs have an important departure in that the the exhaust pipe, instead of turning directly toward the rear, has been carried forward in a long, easy bend, coming as close to the rear of the radiator as possible and then passing beneath the engine supports to the muffler at the rear. The close proximity of the exhaust pipe to the radiator and the cold air flowing through it have produced an internal cooling and condensing effect which has increased the vacuum pressure in the exhaust system and in this

way has produced superior and more complete scavenging, which always results in greater power.

In some six-cylinder motors and all in the eight-cylinder forms now being produced, a similar result has been attained by using double sets of exhaust pipes, leading to a pair of distinct mufflers on opposite sides of the chassis or else to one unusually large one. In the case of the six-cylinder engines, usually the first three cylinders have been considered as one group with their own exhaust pipe and muffler, while the rear three formed the other group. In the case of eight-cylinder V-types, the right-hand group formed one unit for exhausting purposes, and the left-hand lot of cylinders the other.

**Effect of Large Ports on Silence of Motor.** While it has no bearing upon the subject under discussion, this seems a good place to mention the fact that anything tending to make more complete, easier, and quicker any natural function of the motor, as the inflow of fresh gas, the outflow of burned gases, etc., also tends to increase its silence, as well as to increase its volumetric efficiency. This combination, with the demand for more economical motor cars, has brought about the high-speed small-bore motor of today. To make this statement more pointed, it should be said that motors are now being constructed and sold in many popular types of car, which have a bore one inch less than it was considered practicable to build five years ago.

**Manograph Cards.** Before turning to the two-cycle form of motor and the diagrams, both theoretical and actual, it will be well to look at some manograph cards in order to see just what kind of cards the manograph makes and how they compare with those made by the steam-engine form of indicator.

In Fig. 66 is presented what might be called a good card. This was taken from a motor of 120-millimeter bore (4.72 inches, in round figures, $4\frac{3}{4}$) by 130-millimeter stroke ($5\frac{1}{8}$ inches), running at about 1,100 r. p. m. As will be seen at once, this is a combination of a number of successive diagrams, superimposed. The line *DB* indicates excellent admission, with a slight rise near the end of the line, showing a slight increase in pressure due to the inertia of the inflowing gases. Then *BF* shows a good compression line, indicating that the amount of gas admitted has been good, that is,

that admission had been complete. Next, the vertical line from $F$ upward indicates a first-rate explosion.

From the maximum explosion point down to $A$, the curve indicates the expansion. At $E$ will be seen the variation in the successive cards, all of them good but varying slightly from one to another as a better or more complete charge was drawn in, a slightly higher compression pressure obtained, a better or hotter spark produced, or according to other conditions in the cycle. The sharp

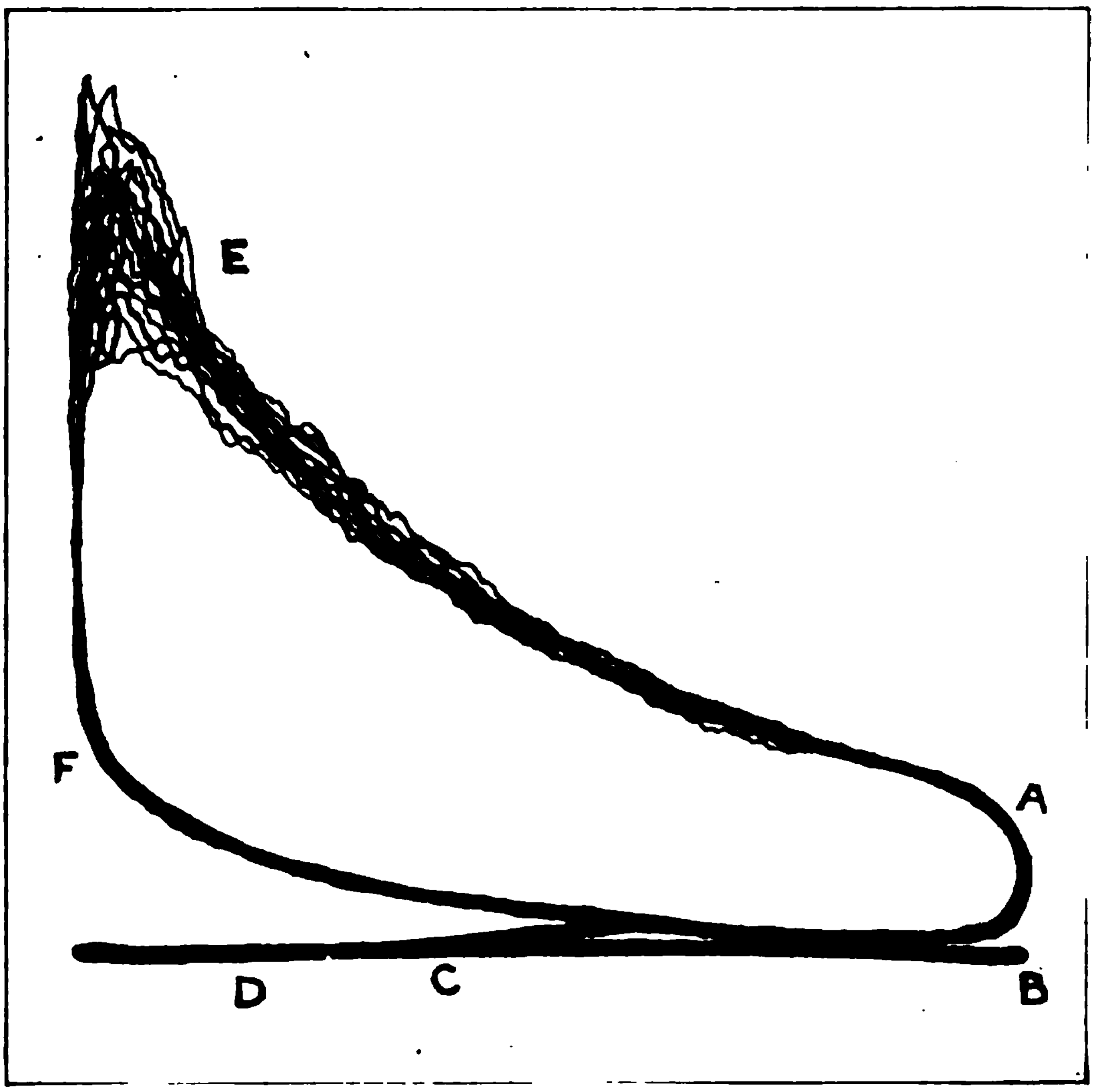



Fig. 66. A Good Manograph Card from a Medium-Sized Four-Cylinder Motor, Showing How a Large Number of Cards Are Taken at Once

end of the expansion curve at $A$, which indicates the opening of the exhaust valve, is very good, as is also the line from $A$ to $D$ and the end of the exhaust stroke. Near the end of this it will be noted that the exhaust line goes below the intake line, indicating a slight vacuum in the exhaust system.

Fig. 67 shows another card taken from the same engine but at a reduced speed, which was being lessened further as the card was taken. The mixture was good, and the charge very complete, while

the slower speed allowed of a better mixing of gas, a superior diffusion of the gases in the cylinder, and a better explosion. The lower pressures of admission and exhaust do not show up as plainly, but the explosion line above *F* is very marked. The agitation in the gaseous mixture is plainly shown in the several waves of the first part of the expansion curve at *E*. Similarly, a good free exhaust is indicated from *A* to the base line and to the end of the stroke at *D*.

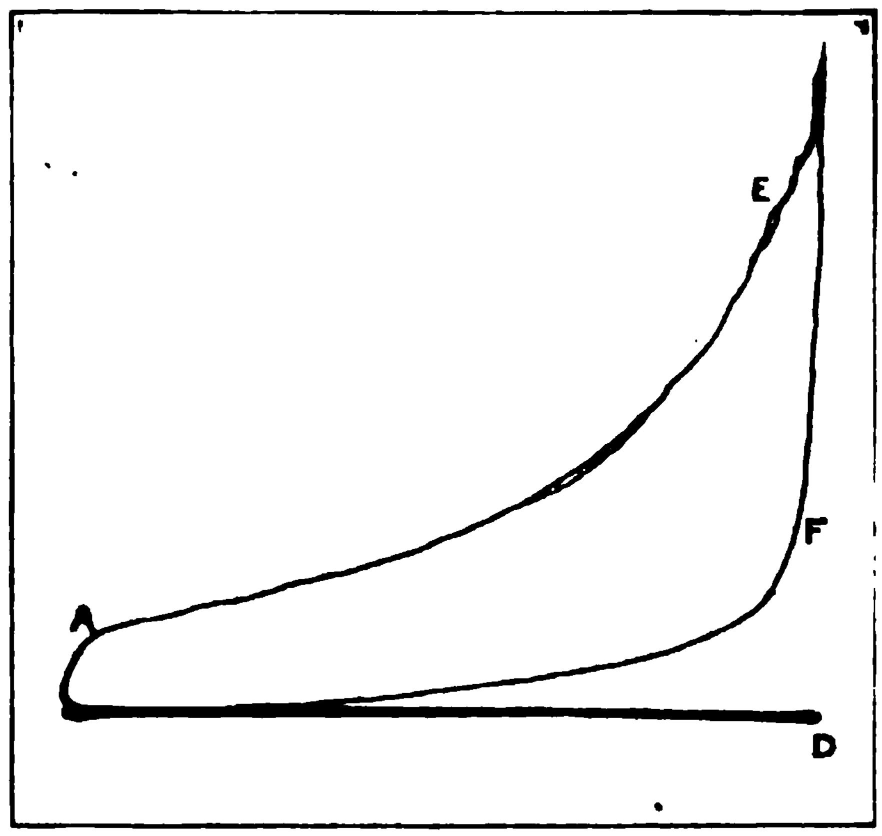



Fig. 67. Another Good Manograph Card, Taken on the Same Motor When Slowing Down, Consequently Showing a Smaller Area

Fig. 68 points out the evil results of retarded spark, this curve indicating the loss of power due to this cause. Note that from *F* upward the curve is not vertical as in the preceding diagrams but slopes off to the left. This, of course, indicates a loss of power. Note also the poor expansion curve from *E* downward, and the comparatively poor exhaust, starting too early and continuing too long and too slowly, as indicated by the length and slope of the curve around *A*.

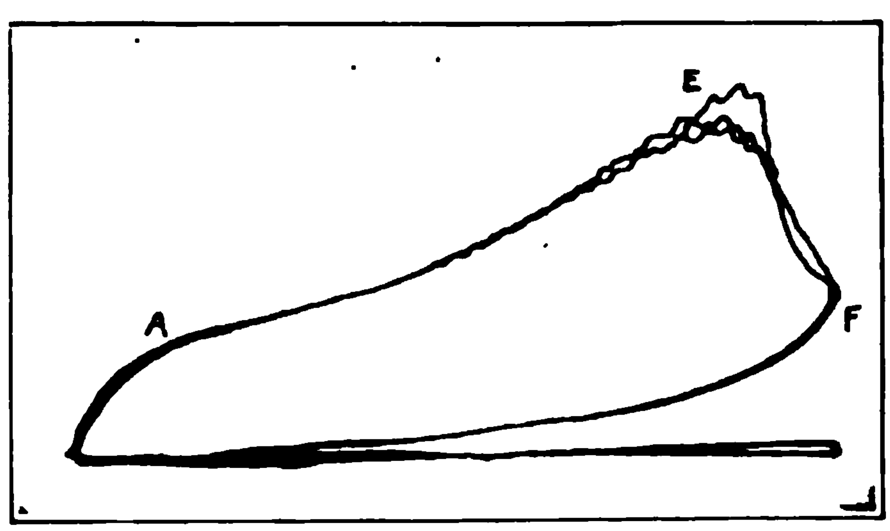



Fig. 68. A Manograph Card from the Same Motor, Indicating the Disadvantages and Results from Over-Retarded Spark

The diagram at Fig. 69 indicates poor compression. This may be caused by leaking piston rings, a piston or cylinder which has worn oval, too small or restricted inlet ports or valves, and a number of other things. The curve *BC* represents the intake, in which it will be noted first that it starts higher than usual, the upturn at *B* indicating that the exhaust closes too soon, leaving gases under pressure in the cylinder. The droop in this line indicates the remarkably poor suction, which is followed by the line *CDE*, indi-

cating the compression and expansion, while $EFA$ indicates the expansion and beginning of the exhaust. It will be noted that all of these are poor, the fact of the expansion line being below the compression line indicating negative work, that is, this shows that more power was required to compress the gases than they gave out during their explosion and subsequent expansion. The exhaust line $AB$ is fairly good, excepting only the early closing as previously pointed out, indicating that the trouble here lies mainly in the suction (carburetion system), compression, and expansion (cylinder construction and condition), with incidentally a poor spark (ignition system).

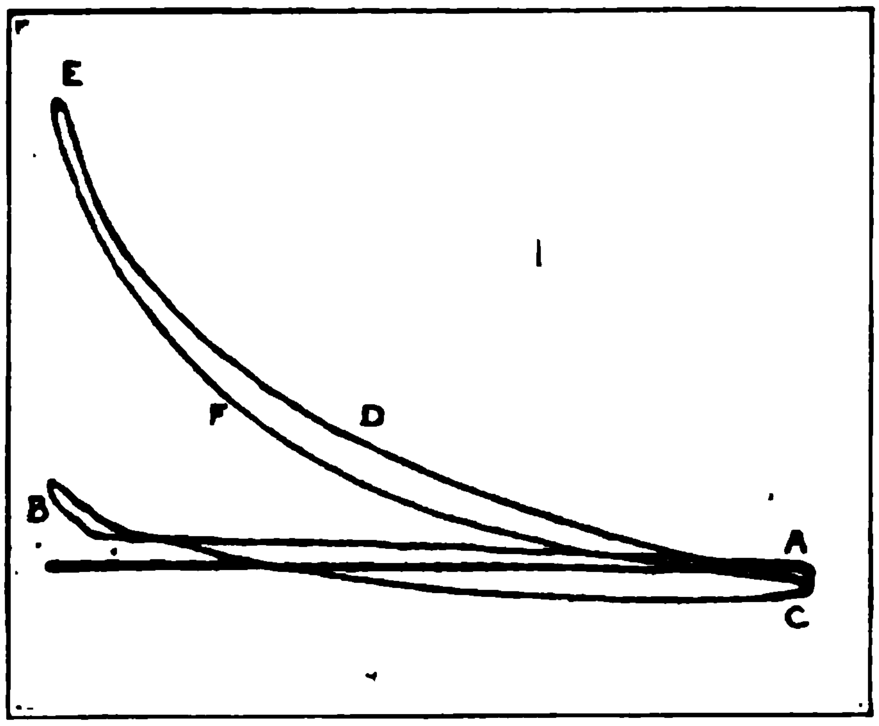



Fig. 69. A Manograph Card Indicating Remarkably Poor Compression and What It Produces in the Cycle

Finally, Fig. 70 shows a diagram taken from an engine with a suction inlet valve. This form is no longer used for automobile engines, but is of interest because it indicates that this form of valve had a considerable influence on the power of the motor. It will be noted that the inertia of the valve was considerable, and the suction not sufficient to hold it wide open all of the time. This can be noted in the waves of the admission curve. Its influence on the power can be seen in the poor explosion line, following a very good compression curve, and this in turn, followed by but a fair expansion. Finally, there is shown a poor exhaust, as indicated by the rising straight line. This means increasing pressure as exhausting proceeded, whereas it should show a drop, if anything.

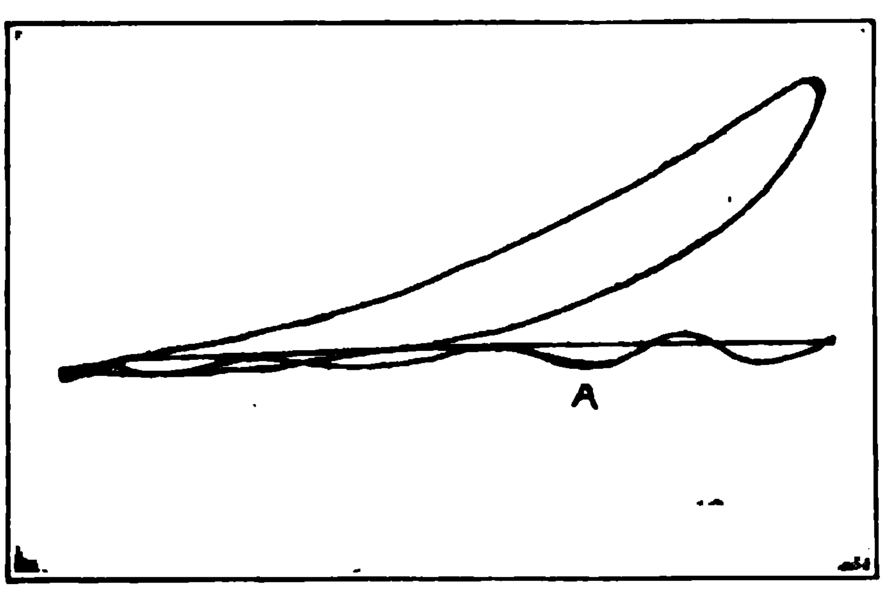



Fig. 70. A Manograph Card Taken from an Engine with a Suction Inlet Valve. Note Variation in Suction Stroke

## TWO-CYCLE MOTOR DIAGRAM

The compression, explosion, and expansion lines of the indicator diagram are the same for the two-cycle as for the four-cycle motor, the only difference between the two types being in the way the exhaust and charging actions are carried on. In Fig. 71 is shown the indicator diagram of a motor which exactly follows the ideal two-stroke cycle. The exhaust opens at $A$, the burned gases escape, the intaking of the charge commences and is completed at $B$, where compression commences. From the above it is seen that the exhaust and intake actions must be done during the time that the piston moves from $A$ to the end of the stroke $C$, and back again to $B$.

**Admission of Charge.** The very short interval of time between the beginning of the exhaust and the admission of the new charge (which enters as soon as the pressure in the cylinder has fallen enough to permit the admission valve to open) makes premature ignition of the charge, or back-firing, of not infrequent occurrence. If the mixture is weak, or the speed is very high, so that the charge is still burning when admission begins, or if the frequency of the explosions brings any part of the cylinder to a red heat, the charge will be ignited on entering, and the explosion then travels back to the crank case, which has to be made strong enough to resist it.

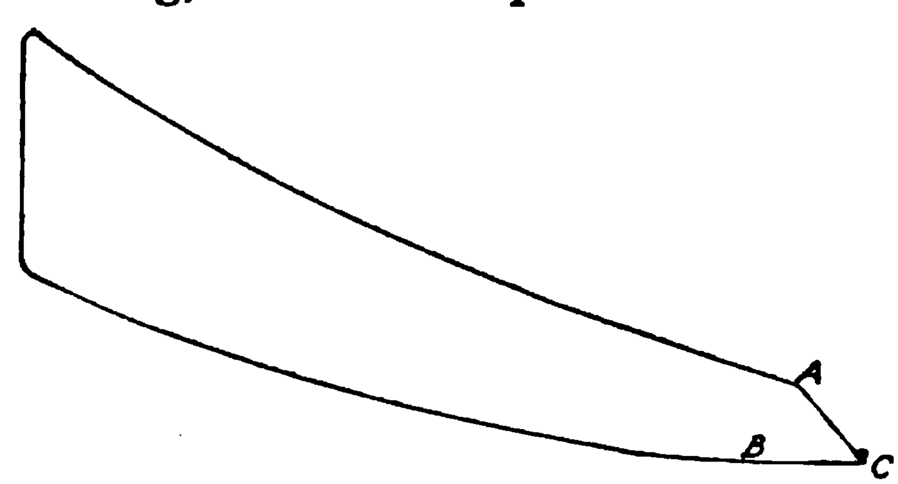



Fig. 71. Ideal Two-Cycle Diagram

In all explosion motors a certain amount of work has to be done in getting the explosive mixture into the cylinder during the suction stroke, and in expelling the exhaust gases during the exhaust stroke. This gas-friction work is represented on the indicator card of an Otto cycle motor by the negative loop, Fig. 72, which has to be subtracted from the positive loop in order to give the indicated horse-power of the motor. In the four-cycle motor this negative work is usually from 2 to 5 per cent of the total work, and is a dead loss. In the two-cycle motor, considerably more work must be done in order to get the gas into the cylinder. The time available for the admission of the charge is extremely short. In a small high-speed motor, it will be from one- to two-hundredths of a second; in a large two-

cycle motor, it may amount to one-twentieth of a second. In an case it will not be more than one-third to one-fifth of the time available for admission in a four-cycle motor.

*Pre-Compression.* In order to overcome the back-pressure of the exhaust, and also in order to be able to enter with the very high velocity necessitated by the short duration of admission, the explosive mixture has to be pre-compressed to 8 or 10 pounds above atmospheric pressure before its admission to the cylinder. Whether this pre-compression is done in the crank case, as in small motors, or in separate compression pumps, as in large engines, it requires the expendi-

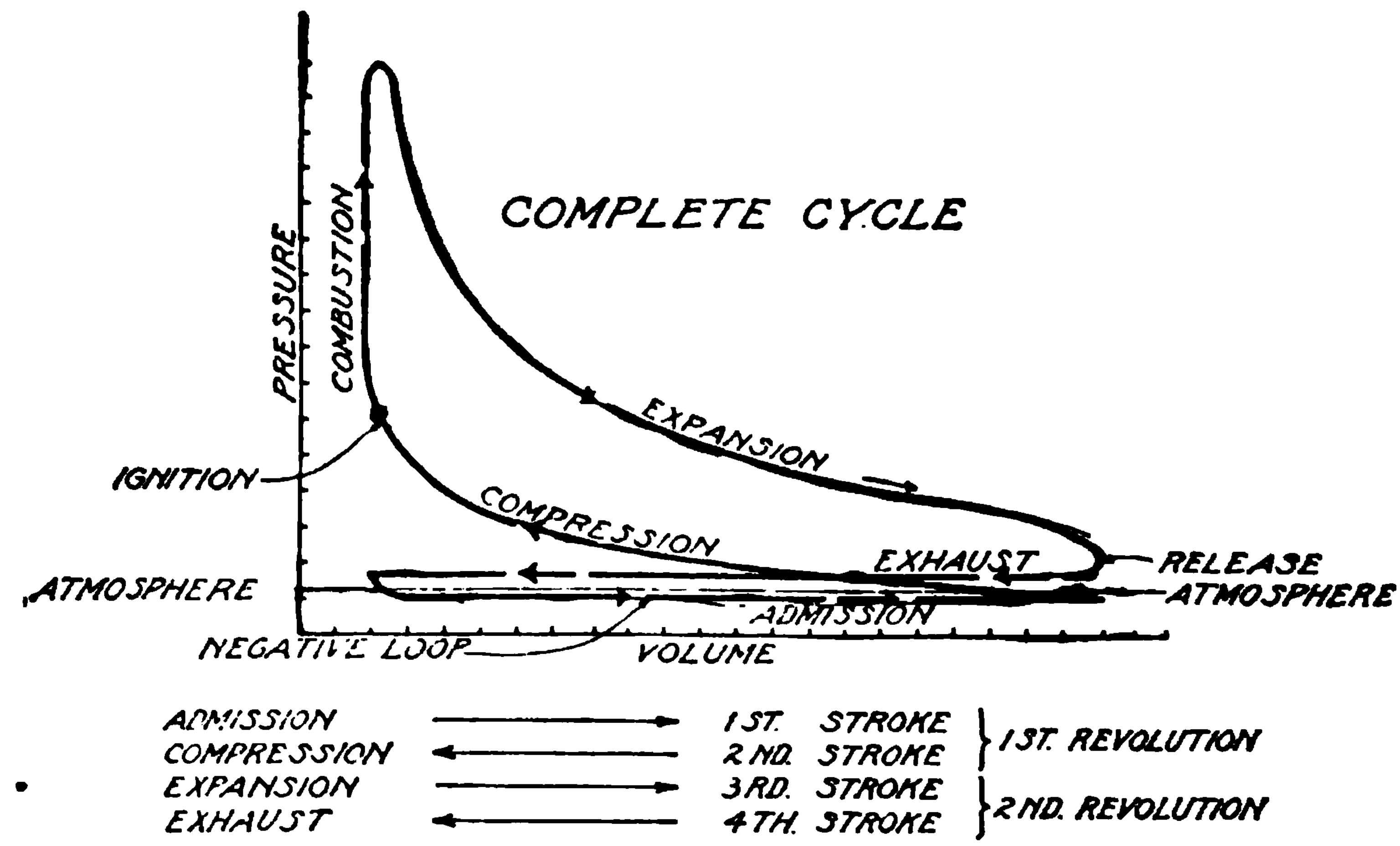



Fig. 72. Diagram Showing Operations of Four-Stroke Cycle. Lower Part of Diagram, Called the Negative Loop, near Atmosphere, Exaggerated

ture of a considerable amount of work—an expenditure which decreases the available power of the motor without giving anything in return other than the possibility of maintaining the cycle of operations. This loss of power in compressing the charge is ordinarily from 15 to 20 per cent of the total work done in the cylinder.

**Valve Timing.** Another loss of efficiency in the two-cycle motor results from the fact that the admission and exhaust ports are open at the same time. An endeavor is made to have the exhaust port close before any of the entering charge has reached it; but it is not practically possible to accomplish that—particularly in a motor which is to run at various speeds. If, in an endeavor to prevent such loss of charge direct to the exhaust, the exhaust port

ses early, too large a volume of the exhaust gases will be retained the cylinder; the amount of the charge which can enter will be rrespondingly decreased; and both the efficiency and the capacity the motor will suffer. In large engines, this trouble is to a great tent obviated by forcing air into the cylinder slightly ahead of e explosive charge, and closing the exhaust port when the charge fresh air is passing through. This device is also valuable in eventing back-firing of the charge.

**Scavenging.** The success of the two-cycle operation depends imarily upon how thorough the scavenging action is carried out, nce upon this depends the explosibility of the charge, as well as s volume, which in turn determine whether the engine runs at all, nd if so what its efficiency will be.

For successful action, point *A*, Fig. 71, should be at atmosheric pressure, any increase above that given tending to increase he volume of exhaust gases remaining in the cylinder as well as he work done by the piston during exhaust. Practice has shown hat scavenging, in order to be thorough, must be commenced omewhere between *A* and *C*.

**Throttling.** The power of a small two-cycle motor can be varied y throttling, that is, by varying the amount of the charge taken into he cylinder. This is accomplished either by throttling the admission o the crank case, or else by throttling in the by-pass between the crank case and the cylinder. There is probably but little to choose between these two methods.

**Reversibility.** Besides its simplicity and compactness, the two-cycle motor may claim reversibility as one of its advantages. The direction of rotation in the valveless two-cycle motor is determined solely by the timing of the ignition. It is possible to reverse such a motor merely by making the point of ignition very early. This causes an explosion well before the ending of the compression stroke and may develop sufficient pressure to stop the piston before it gets to the end of the stroke and start it going in the other direction. When once started in the other direction, the ignition, if unchanged, will be a very late ignition, giving comparatively small power; shifting the ignition back a little will give the motor its full power in its reversed direction. This process is practicable only in motors with light reciprocating parts; it is most convenient for small motorboat use.

**Summary.** In theory, the two-cycle motor develops about 65 per cent more power than a four-cycle motor of the same size and speed; it uses from 10 to 20 per cent more gas per brake horse-power. In actual practice, however, it has been difficult for two-cycle designers and advocates to show more than 10 per cent increase for equal size, while the two-cycle form cannot produce as low a minimum nor as high a maximum speed. The latter has a large influence on the power output, as the four-cycle engine develops the greater part of its power at the upper or high speed end of the power curve. Consequently, the maximum output of a four-cycle motor has always been greater than that of a two-cycle motor of equal size because of the greater speed possibilities of the former. Moreover, the majority of car manufacturers and independent designers have, in the past six or eight years, worked on the four-cycle form with the result that it has approached a high state of perfection. The same can not be said of the two-cycle motor.

Except for the above-mentioned differences and the difference in the form of the diagram, as has just been pointed out, the thermodynamics of any two-cycle type of motor is exactly the same as that on any four-cycle type.

## FUELS

Explosion motors can be made to work with any explosive mixture, those of air with *gaseous* fuels being naturally the mixtures most easily made and controlled. Mixtures of air with *liquid* fuels offer generally no particular difficulty, but those with *solid* fuels (such as powdered coal), although they have been tried, are not practicable on account of the ash which remains in the cylinder and rapidly abrades it. The single exception to the above statement is naphthalene. As will be described later, this is a solid fuel which has been converted first to a liquid and then to a gas, with very great success abroad, and at a surprisingly low cost. A number of French and English commercial vehicles are now being operated upon it. Mixtures of two different kinds of liquid fuels, and of a solid and a liquid fuel have generally been successful where the two components were carefully chosen as to their suitability. As an example of this last statement, kerosene and gasoline mixtures will operate successfully where kerosene alone can not. Many drivers

economize on their fuel bills in this way, adding kerosene in quantities up to 40 per cent of the total to their gasoline. Similarly, with gasoline and alcohol, kerosene and alcohol, naphthalene in gasoline or kerosene (when the fuel is preheated), and others.

Table II gives the heat values for most of the commercially available fuel materials for explosion motors.

The liquid fuels are the only ones with which we are concerned, and of these gasoline is by far the most important, since it is the one almost exclusively used in the motors which we are considering.

**Petroleum Products.** Crude petroleum furnishes us the following commercial products for power purposes: Gasoline, naphtha, kerosene, gas oil, and crude oil.

These products are separated from the crude petroleum by distillation, *i.e.*, the crude petroleum is heated and its various products are given off as vapors; the lightest or most volatile product is given off first, then as the temperature is raised still higher, the next most volatile ingredient is given off, and so on through the entire list.

Rhigolene, sp. gr.* 0.60, distills off at 113° F.; cymogene, sp. gr. 0.625, at 122° F.; gasoline, sp. gr. 0.636 to 0.657, at from 140° to 158° F.; C. Naphtha, sometimes called benzine, sp. gr. 0.66 to 0.70, at from 158° to 216° F.; B. Naphtha, sp. gr. 0.71 to 0.72, at from 216° to 250° F.; A. Naphtha, sp. gr. 0.72 to 0.74, at from 250° to 300° F. Various authorities differ concerning these values, but the ones here given are safe average figures.

*Gasoline.* What we in America know as gasoline is really a combination of the above fractional distillates whose specific gravity runs from 0.63 to 0.74†. The boiling point of gasoline such as is usually used in explosion motors ranges from 150° to 180° F., and

*Specific gravity.

†Specific gravity is figured in two ways, one a decimal quantity and the other an arbitrary figure, as determined on the scale of an instrument known as a Baumé hydrometer. The latter figures are called degrees Baumé. This quantity is used in America more than the actual specific gravity, although the former is usually spoken of as the specific gravity. The increase in weight of the usual fuels, as we pass from the lighter gasoline up to kerosene, and beyond that to heavier forms, would be reflected by the specific gravity. As everyone knows, however, we speak of gasoline as getting poorer, now we get but 56 whereas we used to get 76, etc. These figures refer to the Baumé scale, which gives a lower reading for a heavier liquid. Thus specific gravity may be figured from degrees Baumé by adding the Baumé reading to 130, and then dividing 140 by the result, or

$$\text{Specific Gravity} = \frac{140}{130 + \text{Baumé}}$$

Using this on the figures given above, we find that 56 Baumé equals .75 s. g. and 76 Baumé, .68 s. g. The remark then translated into actual specific gravity would read, now we get .75 gasoline, whereas we used to get .68. This is correct, for present-day fuel is heavier than that of

TABLE II

Explosion Motor Fuels

| Gases, Vapors, Liquids, and Solids | Heat Units* per Pound | Heat Units per Cubic Foot |
|---|---|---|
| Hydrogen | 61,560 | 293.5 |
| Carbon | 14,540 | |
| Crude Petroleum | 18,360 | |
| Kerosene | 22,000 | |
| Benzine | 18,450 | |
| Gasoline | 18,000 | |
| Alcohol, Methyl | 20,000 | |
| Denatured Ethyl Alcohol | 13,000 | |
| Acetylene | 21,490 | 868 |
| 19-can. power Illuminating Gas | | 800 |
| 16-can. power Illuminating Gas | | 665 |
| 15-can. power Illuminating Gas | | 620 |
| Gasoline Vapor | 18,000 | 692 |
| Natural Gas, Leechburg, Pa. | | 1050 |
| Natural Gas, Pittsburg, Pa. | | 890 |
| Water-Gas | | 290 |
| Producer-Gas | | 150 |
| Suction-Gas | | 135 |

*A heat unit or British thermal unit (B. T. U.) is, practically speaking, the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

the flashing point‡ of the liquid ranges from 10° to 14° F. A mixture of one part of this gasoline vapor to 7.3 parts of air produces what is theoretically a perfect combustion mixture. A decrease in the proportion of air may leave, as a residue in the exhaust, unconsumed vapor, while an excess of air up to a limit of 10 parts of air to 1 part of vapor may increase the fuel efficiency. As a matter of fact, the modern automobile engine will operate on any mixture between 5 to 1 and 15 to 1.

A sample of gasoline of specific gravity 0.71 showed 83.8 per cent carbon, 15.5 per cent hydrogen, and 0.7 per cent impurities, and had a heating value of 18,000 B. T. U's per pound. The various grades of gasoline differ mostly by the percentage of hydrogen

five years ago. By referring to the s. g. of kerosene, it can be figured out readily that the actual case is that fuel now sold as gasoline contains a considerable amount of what was formerly sold separately as kerosene. Except for the name this is no disadvantage, but on the contrary an advantage so long as the carbureter will handle it, for kerosene contains a greater number of heat units per pound.

‡The flashing point of a substance is the lowest temperature at which it gives off vapor in sufficient amount to form with the surrounding air a mixture which is capable of burning when ignited.

contained. A gallon of liquid gasoline will in the form of a vapor fill about 160 cubic feet, or about 1,200 times its liquid bulk. Gasoline of 0.74 specific gravity will weigh 6.16 pounds per gallon, and its pure vapor, which occupies about 26 cubic feet per pound, has a heating value of 690 B.T.U's per cubic foot. The recent shortage of gasoline has produced many efficient kerosene vaporizers and caused a wide use of kerosene, both straight and mixed.

*Kerosene.* Kerosene is distilled from crude petroleum at a temperature of 300° to 500° F. Its specific gravity is 0.76 to 0.80.

*Coal Gas.* Coal gas has a specific gravity of 0.80, given off above 500° F. Crude oil remains after the above distillation process.

*Miscellaneous Distillates.* The former simple division of crude petroleum products into four parts, gasoline, kerosene, coal gas, and crude oil, is no longer correct. The tremendous demand for motorcar and boat fuels has brought about the need for a larger percentage of gasoline, which has been supplied by making it heavier through the inclusion of much of what was formerly sold as kerosene. To keep up the quantity of the latter, this too has been made heavier by the inclusion of considerable quantities of what formerly was distilled over as coal gas. In addition, the distillation is further split up by the separation of the naphthas, first the lighter benzine naphtha, then naphtha, then benzine. Finally, what was formerly lumped as crude oil remainder is now split up into a number of different oils, with the final remainder, now called "residuum" or "tailings". The latter is sometimes fluid, but more often a viscous semi-solid dark-green or dark-brown substance with an unpleasant odor. As a matter of fact, several carburetors have been developed on the Pacific Coast, by means of which this former waste material can be first liquefied, then converted into a gas and burned in motor truck engines. When this is done, an important economy is effected, for this material sells for about three cents a gallon, and in some localities as low as 1½ cents, when sold in barrel lots.

**Denatured Alcohol.** There are two kinds of alcohol, viz, (1) ethyl alcohol ($C_2H_6O$), which can be made from corn, rye, rice, molasses, beets, or potatoes, by a process of fermentation and distillation; and (2) methyl or wood alcohol ($CH_4O$), which is obtained from the destructive distillation of wood. Ethyl alcohol is that which is present in alcoholic beverages; wood alcohol is a virulent

poison. Denatured alcohol is ethyl alcohol which has been rendered unpalatable and unfit for consumption by the addition of wood alcohol and a little benzine or other substance. It gives up about 11,800 B. T. U's per pound on burning; consequently it does not give up much more than one-half as much heat per pound as gasoline or kerosene. The weight and volume of denatured alcohol required to develop a given power in a motor is considerably greater than the amount of gasoline for the same power; and, therefore, if a gasoline motor is to be used with alcohol, the orifices in the carbureter or other spraying device have to be enlarged so as to admit a greater volume of the liquid. Wood alcohol can not be used by itself in a motor, as it corrodes the cylinder. Denatured alcohol, in its volatility, lies between gasoline and kerosene, the amount of vapor which it gives off to air that passes over it being generally sufficient to give an explosive mixture, if the temperature of the air and alcohol are above 70° F. With an ordinary spray carbureter a considerable excess of alcohol may be sent to the cylinders, as such carbureters act also as atomizers.

Recent tests have demonstrated that any gasoline or kerosene motor can operate with alcohol without any structural changes, and that about 1.8 times as much alcohol as gasoline is required to develop the same power. Alcohol can be used with greater compression, as there is little danger of pre-ignition through too much compression on account of its comparatively high ignition temperature and also because it is always mixed with some water. An alcohol motor can be made to give somewhat higher power than a gasoline motor of the same size. It is not as sensitive to poor adjustment of the explosive mixture; that is, it will work with a great range of strength of mixture, and it does not accumulate a deposit of carbon inside the motor. An explosion motor of good design should use about 1.15 pounds of alcohol per brake-horse-power hour; of gasoline, 0.7 pound.

Despite all these advantages, denatured alcohol as a fuel has not come into wide use, partly because of its high price as compared with gasoline and kerosene, partly on account of poor distributing facilities, and partly for other reasons. It has, however, attained a considerable use among motor car owners as an anti-freezing solution and as a decarbonizer. For the former, a small quantity is

added to the water in the radiator in the winter months, reducing the temperature at which this will freeze, according to the quantity added. It is possible to add enough to give a solution which will not freeze until 32 degrees below zero is reached. As a decarbonizer or remover of carbon formations in the cylinder, denatured alcohol is excellent, while its use is the essence of simplicity. It is to be hoped that the production will be materially increased in the next few years so as to reduce the price, increase its availability, and thus help out the fast-failing gasoline supply.

**Other Automobile Fuels.** *Benzol.* In England, a fuel called "benzol" is used to a considerable extent. This is a by-product of the destructive distillation of coal, that is, it is produced in the manufacture of coal gas. In large plants a considerable quantity can be made, for the yield is something like three gallons per ton of coal burned. It is naturally a foul-smelling, dark-brown liquid, but by a refining process is made a transparent white, like water, and the odor partly removed. It has a specific gravity of .88 at 60 degrees F., a flash point of 32 degrees F., and a heating value of about 17,250 B. T. U's per pound. Although not as volatile as gasoline, it starts readily and, when carefully refined, does not leave a residue, or carbonize in the motor. In Germany the lack of gasoline has brought forth a benzol-alcohol mixture. Up to 1 benzol to 5 alcohol it gives better mileage than gasoline or pure benzol.

*Electrine.* In France, a mixed fuel composed of half benzol and half denatured alcohol is much used, this bearing a number of trade names. One of these, "Electrine," has an s.g. at 15° C. of .835.

*Naphthalene.* Mention has been made previously of a solid fuel, naphthalene. This is a white solid substance, produced during the manufacture of gas from coal, and previously was a waste product. It now sells at about 3 cents a pound. In a less pure state it is well known to all in the form of camphor balls, so-called. To use this as a fuel in an automobile engine, it must be melted to a liquid, then turned into a gas and mixed with the right proportion of air. None of these offer any particular difficulty, and it has been used abroad with marked success, particularly on a long test by a 40-horse-power motor truck. After the trip, the cost, using naphthalene, figured out to 0.6 of a cent per horse-power hour, while a similar truck, running side by side with this one, on gasoline cost 2.6 cents

per horse-power hour. In its first trial then, this fuel showed four times the economy of gasoline.

*Solid Gasoline.* A number of attempts have been made to produce gasoline in a solidified form so that it could be handled more easily and much more safely. In Europe, this has been accomplished satisfactorily, the resulting substance being of about the consistence of jelly. In general its properties are about the same as liquid gasoline, except that it occupies less space, a gallon when solidified taking up about 185 cubic inches as compared with 231 before. The principal argument against its use is the size of the vaporizing device needed to change it to a gas and add air.

**Gas and Gas Generators.** Scarcity of fuel and unusually high prices in the last two years have brought out the use of gas in various forms. An English truck (and motor bus), which has been very successful, uses ordinary gas from the city's mains, compressed into tanks and diluted with air as carbureted and used. A car has been developed to use a very high grade gas produced from peat. American workers have brought out a device which will handle water, gas, and other forms having a high fuel value and which can be compressed readily. In outward appearance, these cars do not differ from any other, the carburetor or gasifier and the extra tank, which is larger than an ordinary gasoline tank, being the only differences. This use of gas opens up wide possibilities for the future.

## FUEL MIXTURE

**Explosibility.** If a combustible vapor be mixed with air in certain proportions, the result is an explosive mixture. Every mixture will possess certain qualities, depending upon the ratios of air to vapor in each case, and under the same conditions certain pressures and temperatures will result from the combustion of each mixture. The highest pressures and temperatures result from the explosion of those mixtures which contain just sufficient oxygen to support the combustion of the explosive vapor contained in the charge. According to Clerk, the highest velocity of flame propagation occurs when the vapor is a trifle in excess of that contained in the ideal mixture.

Any variation in the composition of the mixture either way from the theoretical ratio results in decreasing the maximum pres-

sures and temperatures of combustion and in making the explosion occur more and more slowly until finally we have a slow combustion, *i.e.*, the mixture ceases to be explosive. It has been found that approximately 15 pounds of air are required per pound of gasoline for the true explosion mixture.

In actual practice, to make sure that complete combustion results, an excess of air is usually employed, the latter being beneficial also in that the maximum temperatures are reduced, which reduce the per cent of heat lost to the cooling water. This excess also reduces the danger of pre-ignition. The theoretical ratio of the number of volumes of air per unit volume of gasoline vapor for the true explosive mixture is between 25 and 30, while the explosive range of the mixture extends below these values to about 19.5 and above them to a value of about 40.5.

## HORSE-POWER AND RATING CALCULATIONS

The unit of mechanical power, the *horse-power*, is equivalent to the performance of 33,000 foot-pounds of work per minute. In a four-cycle motor, as an explosion occurs every two revolutions, there are twice as many revolutions as explosions or cycles per minute. To calculate the horse-power of such a motor, therefore, the number of foot-pounds of work done at each explosion (call it $W$) must be multiplied by the number of explosions or by one-half the number of revolutions per minute $\left(\frac{\text{r.p.m.}}{2}\right)$, and this product divided by 33,000. The result will be the horse-power (h. p.) of the motor. Expressing this in equation form it becomes

$$\text{h.p.} = \frac{W \times \text{r.p.m.}}{2 \times 33{,}000}$$

**Indicated Horse-Power.** In actual practice the indicated horse-power of an automobile engine means little or nothing. What is needed is a simple, easily understood formula by means of which anyone can figure out a rating horse-power. This is used for purposes of comparison, for a basis of automobile taxation, for legal purposes, handicapping races, and otherwise. In gasoline engines for stationary power purposes, and, at times, in automobile motors, the indicated horse-power is desired for figuring. When this is the

case, it is figured from the indicator card by means of the following formula:

$$\text{i. h. p.} = \frac{PLANK}{33{,}000}$$

in which $P$ is mean effective pressure (m.e.p.) in pounds per square inch; $L$, length of stroke in feet; $A$, piston area in square inches; $N$, number of cycles per minute or one-half the number of revolutions per minute; and $K$, number of cylinders.

The mean effective pressure $P$ is obtained from the indicator card by going around it with a planimeter* in the way in which it was traced, that is, in order *1-2-3-4-5-1*, Fig. 73. The indicator card consists really of two areas or loops, of which *3-4-5* represents positive work, and *1-2* negative work. The total work done on the piston is represented by the difference between these two areas. The small area *1-2* represents the work done in overcoming the friction resistance of the gas when being admitted to and expelled from the cylinder. It is work that has to be done by the motor; is a definite loss of power; and should be made as small as possible. The area *3-4-5* is the work that is actually done on the piston, less the work required to compress the gas; it is the true work of the cycle, all of which would be available for driving the engine, were it not for the gas-friction resistances represented by the area *1-2*. See also the negative loop, Fig. 72. If a planimeter is made to trace the diagram in the order in which it was drawn, it will go around the area *1-2* and *3-4-5* in opposite directions; that is, if it goes around one clockwise, it will go around the other counter-clockwise. The consequence is that the readings of the planimeter will give the desired difference in square inches between the two areas *3-4-5* and *1-2*. The mean effective pressure is then obtained in the usual manner by dividing this area by the length of the diagram and multiplying by the "scale" or constant of the indicator spring.

**Mechanical Efficiency.** The figures just given refer to the indicated horse-power (i.h.p.), which is the work done upon the piston by the charge. The object of the motor, however, is to drive some other machine or apparatus. It is, therefore, important to rec-

* A planimeter is an instrument which indicates the area of an irregular figure by tracing the boundary of the figure. The area of the indicator card may be approximated by dividing it into a series of rectangles and taking the sum of the areas.

ognize the distinction between the indicated work done in the cylinder and that quantity of work, always smaller, which the motor does against external resistance. This work against external resistance is termed the *brake horse-power* (b.h.p.), or *delivered horse-power* (d.h.p.). The term brake horse-power is usually applied to the power absorbed by a friction brake attached to the rim of the flywheel or to the shaft.

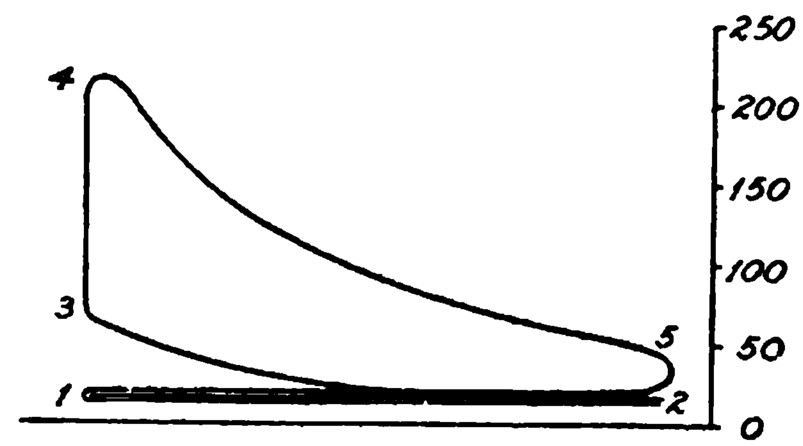



Fig. 73. Indicator Card from Otto Cycle Motor

*Prony Brake.* The most commonly applied form of friction brake is that one known as a prony brake, one form of which is shown in Fig. 74. This device consists of a series of wood blocks *D* connected by a leather or iron strap and arranged so as to rub on the surface of the flywheel of the engine to be tested. The two arms of the brake rest on a pair of scales. The hand wheel, shown at *E*, is for varying the amount of friction. The horizontal distance *R* from the center of the wheel to the end of the arms is known as the brake arm.

In using the brake, the load is applied by turning the screw *E* and is measured by the reading on the scale. Before the load is applied, and the brake arms are resting on the scale, as shown in the figure, the scale must be read to determine the amount required to balance the overhanging brake arms. This amount must be deducted

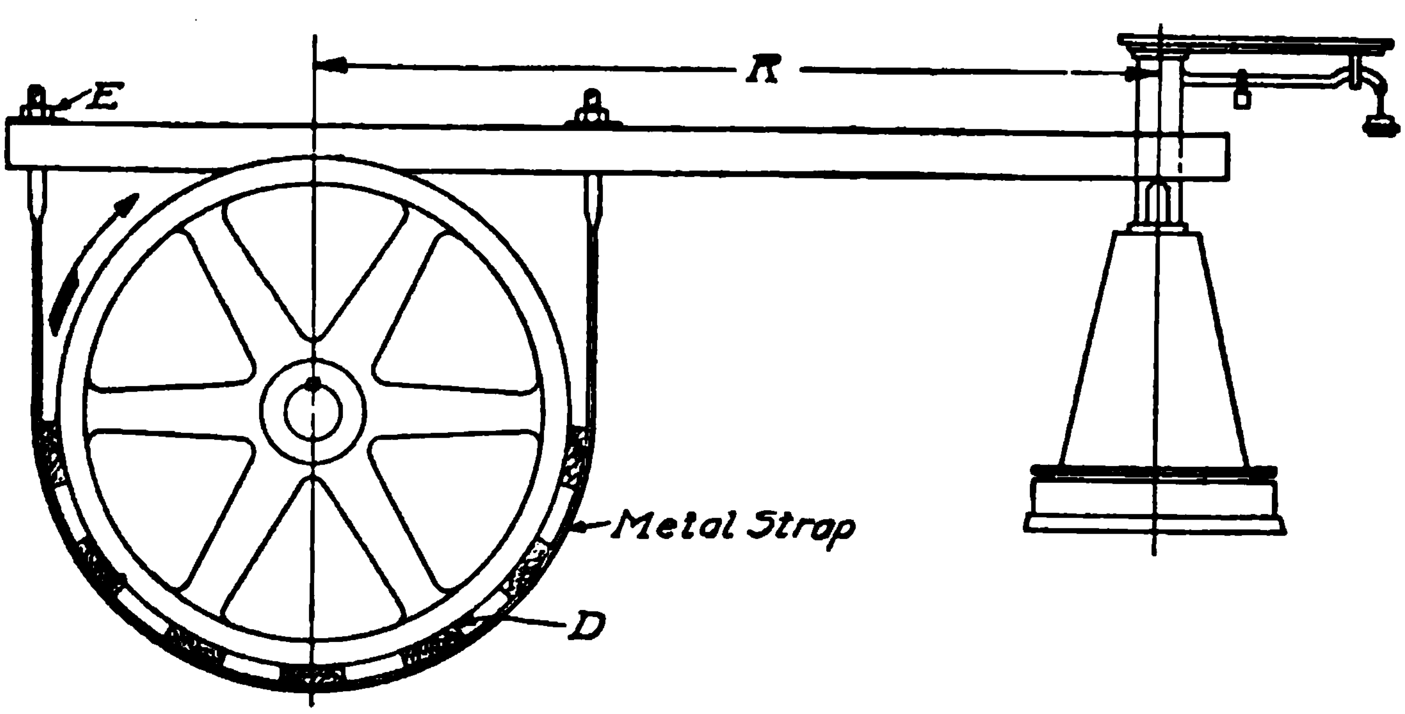



Fig. 74. Prony Brake for Testing Motor Efficiency

from the reading of the scales when the load is applied, in order to give the net load. This may be done in either one of two ways:

The scales can be turned back and readjusted so as to record nothing when the break arm is resting on the scales; or, without correcting the scales, the deduction can be made when the final power is figured out, that is, the weight which the brake arm alone depresses on the scale beam must be subtracted from the total scale reading to give the net load on the scale.

The b.h.p. is calculated by the formula

$$\text{b.h.p.} = \frac{2\pi anW}{33{,}000}$$

in which $n$ is revolutions per minute; $a$, length of brake arm in feet: $W$, the net load on the scales; and $\pi$, 3.1416.
The formula then assumes the form

$$\text{b.h.p.} = \frac{anW}{5252}$$

and with any given brake, the length $a$ will be a fixed quantity, so that that also can be inserted. Suppose it happens to be 4 feet. Then the formula becomes

$$\text{b.h.p.} = \frac{nW}{1313}$$

All the repairman needs to construct a brake of this kind is the scales, a good hardwood beam of about 3 x 5 inches in section, a band of strap iron, a few wooden blocks to fasten to it, and a thumb nut with which to tighten it. For general use, it is best to have a special shop flywheel and make the band to fit this. Then when an engine is to be tested, the flywheel can be removed and the shop wheel bolted on in its place. Otherwise, there would be a lot of bother with the difference in the sizes and shapes of various engine flywheels, and the consequent difficulties of making the brake fit.

The brake horse-power is less than the indicated horse-power by an amount which respresents the loss due to friction of one kind and another in the mechanism of the motor itself.

The ratio of the b.h.p. to the i.h.p. is the *mechanical efficiency* of the motor, that is,

$$\text{mechanical efficiency} = \frac{\text{b.h.p.}}{\text{i.h.p.}}$$

Good motors have a mechanical efficiency of from 80 to 95 per cent, referring to modern automobile motors. Other motors, as stationary

gasoline or gas engines, have a lower figure, say from 70 to 80 or, possibly, 82.

**Estimating Motor Horse-Power.** An inspection of the i.h.p. formula above given will show that if we are able to presuppose some certain mean effective pressure (m.e.p.), we have the most practical way of estimating the horse-power of any explosion motor whose length of stroke, piston area, and revolutions per minute are known.

The mean effective pressure secured in gasoline engine practice ranges from a minimum of 45 or 50 pounds to the square inch, to a maximum of about 125 pounds to the square inch. For the above purpose, 60 pounds may be assumed as very close to the m.e.p. of most automobile motors, though in sleeve valve and other types in which the combustion chamber is approximately spherical, the mean effective pressure will often be as high as 85 pounds. In any case, for a given type of motor there is never any considerable variation from a certain mean effective pressure that is characteristic of its type. This pressure being known, it becomes a matter of simple arithmetic to calculate the power from a given stroke, cylinder diameter, or piston area, at a given number of revolutions per minute, *i.e.*, by a direct substitution in the formula for i.h.p. given on page 77.

For two-cycle motors the compression is usually lower than in the four-cycle type, and it is safe to assume that the m.e.p. is not over 70 to 75 pounds. In applying the formula for the i.h.p. to the two-cycle motor, $N$ becomes the number of revolutions per minute, since there is an explosion in each revolution.

**Electric Dynamometer.** The electric absorption type of dynamometer is a testing device, operating on the same principle as the Prony brake. It is, however, more accurate, more complete, easier to use and, in other ways, has a distinct advantage over the older form of hand-applied brake, which is now nearly obsolete, as well as over other forms of absorption brake, such as the coil of rope form, the water brake, the centrifugal pump, the air fan, and others. The electric type is practically a measuring dynamo, which is driven by the engine being tested and, when so driven a magnetic action is set up between its field pieces and armature, which can be measured precisely in electrical units. When this is done, the quantity,

in foot-pounds of energy exerted through a given radius, is an exact measure of the torque or turning power of the engine.

The radius, like that of the brake arm of the hand-operated form, may be of any desired length, but if $15\frac{25}{32}$ inches is used, this simplifies the usual Prony brake formula to

$$\text{b.h.p.} = \frac{\text{weight in pounds} \times \text{r.p.m.}}{4{,}000}$$

in which the weight is measured by means of a pair of scales, usually of the double-beam type, with a fine reading to pounds and tenths on one beam and a rougher reading for quick but approximate determinations on the other. The revolutions will be indicated by

**Fig. 75.** Electric Dynamometer for Testing High-Speed Automobile Engines
*Courtesy of Sprague Electric Works, New York City*

means of an electric speedometer, supplemented usually by a form of tachometer to be used as a check. With but two variable quantities, the weight and speed, it is possible to lay down the curves for every possible combination of speed and weight, so that the power can be read at a glance by simply following out the two lines to their point of intersection.

With this form of device, it is possible to have the electric loading arranged in such a manner that it resembles the well-known rheostat used on trolley cars, and like it is turned on by means of a rotating handle or wheel. In that case, the tester simply sits at a table making his readings and gradually turning the wheel to increase or decrease the load.

*Auxiliary Apparatus.* When using electrical testing apparatus of this kind, it is possible to have many additional auxiliary features of value. For instance, by turning on the electric current, the dynamo acts as a starting motor to turn the engine over, until it starts. In case the test is to be a long-drawn one, the electrical energy generated need not be wasted as with other forms of brakes, but can be wired to electric motors elsewhere in the plant and utilized, this disposition of it having no influence whatever upon the measurement of the energy. In addition, automatic or self-registering instruments may be had, so that an operator is not needed, after the test has been started, except to stop it. Further, an automatic gasoline-measuring scale may be had, which is electrically operated, this being constructed to register the number of revolutions and the elapsed time for each pound of fuel consumed.

Fig. 75 shows the complete dynamometer with scales and measuring devices, as made by the Sprague Company, while Fig. 76 shows the complete layout of a similar outfit as made by the Diehl Manufacturing Company, this indicating the actual test of a six-cylinder motor.

In Fig. 77 is shown a modern testing room with a number of 8-V motors mounted for testing. This view shows the importance attached to preliminary testing of motors by big manufacturers.

*Importance of Testing to Repair Man.* It is particularly important that the repair man be well equipped in the matter of testing apparatus. In fact, every well-equipped garage should have some form of horsepower testing outfit, either one of those just described or else some similar homemade affair. What is needed by the repair man, however, is not so much a measuring apparatus as a loading device, whereby loads may be thrown upon engines which have hidden troubles, or which have just been repaired, so as to allow the motor to act as it would when actually pulling the car with a standard load.

An advantage of a loading device of this kind is that troubles which are otherwise hard to find can be discovered in a short time inside the shop instead of after long, extended, and expensive outside runs to determine the exact part which is at fault. With a loading device, a stethoscope (such as is described elsewhere in this work) and a full set of electrical testing instruments, a garage or repair man, who is onto his job, can in a short time locate the trouble with any engine, transmission, or any other part of a complete car. With the trouble located, the difficulty is half overcome.

Fig. 76. Electric Dynamometer Coupled up to Six-Cylinder Engine for Test
*Courtesy of Diehl Manufacturing Company, Elizabeth, New Jersey*

The repair man can buy at a reasonable figure testing outfits which are designed solely for the purpose of finding out electrical sources of troubles (and many others) in the shortest possible time. These are called trouble-finding or trouble-shooting outfits, and a number of them are now marketed.

Lacking a stethoscope to use with a testing or loading outfit, many garage men make use of a substitute in the form of a plain steel rod of small diameter. By holding one end of this rod between the teeth with the other end placed on or near the suspected engine part, one can train the ear to recognize, by means of the vibrations

which come to it through the rod and teeth, whether or not the part is running exactly right. In many cases, such a testing or loading outfit is a good preventive of trouble, enabling the owner to locate the trouble and correct it before it can get serious enough to cause excessive difficulty or expense. The adage "A stitch in time saves nine" applies equally well to an automobile and many owners would have much less trouble if they or their chauffeurs understood this better.

**Rating.** At one time practically all automobile engines were given a hyphenated rating, as for instance, 30-60 horsepower. This represented the power developed at a normal speed and the maximum output of which it was capable. In general, the difference was not as great as in the example given, although this represents an actual rating of a well-known American car motor. As has been stated, rating allows of a comparison when the same basis is used by everyone; that is all it is for. Now, ratings are worked out from various formulas. The one used throughout the United States is that known as the S.A.E. formula, after the Society of Automobile Engineers, sponsors for it. This was formerly called the A.L.A.M. formula because the now-defunct Association of Licensed Automobile Manufacturers placed their seal of approval upon it, and brought it into general use in this country. It originated in England, where it is still in universal use as the R.A.C. formula. It is as follows:

$$\text{h.p.} = \frac{D^2N}{2.5}$$

in which $D$ is the diameter of the cylinder bore in inches and $N$ is the number of cylinders. As $N$ is usually 4, 6, or 8, it is possible to simplify the formula to:

$$\text{h.p.} = 1.6D^2 \text{ (for four cylinders)}$$
$$\text{h.p.} = 2.4D^2 \text{ (for six cylinders)}$$
$$\text{h.p.} = 3.2D^2 \text{ (for eight cylinders)}$$

While no account of the stroke appears to have been taken in figuring this out, yet in the original determination of the value of the constant 2.5 used, 1,000 feet per minute was considered as a fair average piston speed. As the length of the stroke determines the piston speed, it is apparent that consideration was given to the

length of the stroke, and that this factor is in the formula. However, for the benefit of those desiring the length of the stroke $L$ incorporated, the following formulas have been developed and are in use: Roberts' formula,

$$\text{h.p.} = \frac{D^2 L N R}{1800}$$

Dendy-Marshall formula,

$$\text{h.p.} = \frac{D^2 S N}{12}$$

substituting the number of cylinders, this becomes

$$\text{h.p.} = .33\ D^2 S \text{ (for four cylinders)}$$
$$\text{h.p.} = .5\ D^2 S \text{ (for six cylinders)}$$
$$\text{h.p.} = .66\ D^2 S \text{ (for eight cylinders)}$$

White and Poppe formula,

$$\text{h.p.} = \frac{D S N}{16}$$

in which, however, the diameter $D$ and the stroke $S$ are in *centimeters*. Substituting the number of cylinders as before, this becomes

$$\text{h.p.} = .25\ DS \text{ (for four cylinders)}$$
$$\text{h.p.} = .38\ DS \text{ (for six cylinders)}$$
$$\text{h.p.} = .5\ DS \text{ (for eight cylinders)}$$

*Racing Boat Formulas.* The following formulas are for high-speed racing boat engines of four-cycle type, and are based on 1,000 feet per minute piston speed. For engines of ordinary design, two-thirds of the above values should be taken; 10 per cent should be added to the ratings if the charge is forced into the cylinders by any mechanical device.

American Power Boat Association,

$$\text{h.p.} = \frac{D^2 N}{2.5338}$$

For motors of less than 6-inch stroke,

$$\text{h.p.} = \frac{D^2 L N}{15.20}$$

*Two-Cycle Formula.* The following are two-cycle engine formulas, the first being by Roberts for racing-boat engines and the next two by the American Power Boat Association:

$$\text{h.p.} = \frac{D^2 L R N}{13{,}500}$$

$$\text{h.p.} = \frac{D^2 N}{2.1008}$$

$$\text{h.p.} = \frac{D^2 L N}{12.987}$$

The above formulas by the American Power Boat Association are only for racing-boat engines. For ordinary two-cycle-boat engines two thirds of the value resulting from the use of these formulas should be taken. For engines having one or more displacer cylinders, the above rating should be increased in the ratio that the displacer pistons' displacement bears to that of the working cylinders.

*Comparison of Power of Two- and Four-Cycle Motors.* It will be noticed that in a two-cycle engine having double the number of power strokes of a four-cycle, the h.p. would be multiplied by 2. This, however, would give an erroneous result, as there are many inherent conditions connected with two-cycle engine design which tend to lower its horse-power output, such as the lower compression, lower m.e.p., due to inefficient scavenging, etc. For these reasons the output varies more in two-cycle engines than in four-cycle engines, and is very often taken as approximately 1.35 of that of a four-cycle engine of the same bore and stroke. There are, of course, exceptional cases where two-cycle engines have shown considerably better than this value, but it is considered an average result.

*Other Testing Work.* There is considerably more to testing than the simple use of a form of dynamometer or prony brake. After bearings have been rescraped and set up, after new pistons or new cylinders, new crank shaft, new cam shaft, or any other important new parts have been added, "running in" is fully as important as testing. After a car has been worked on and important changes made, as new transmission gears, new axle, new driving shaft, new springs, or others of equal import, "running in" on the roads is more important even than testing. The "running in" process makes certain that everything is working right and will continue to work correctly con-

tinuously. In the case of important engine changes it smooths out any rough spots left in machining. Running in of engines after important changes is usually done by driving the engine from an overhead line shaft by means of a leather belt. When this is done, a heavy oil is used for the lubricating system, much heavier than will be used later, this being forced around the system by the power drive. On many cars and trucks, the running in process takes more time, is given more attention, and costs the manufacturer much more than the actual testing. Every good mechanic and repair man should run in each engine or car repaired before delivering it, if only to assure himself that a good job has been done. The running in and testing are in a sense the proof of the work.

## SUMMARY OF EXPLOSION MOTOR INSTRUCTION

**Q. To what is the term explosion motor applied?**

A. The term explosion motor is generally applied to the gasoline engine used as a source of power in automobiles, motor trucks, motor cycles, aeroplanes, motorboats, and small gas and gasoline engines as well. A recently coined term for this entire field is *automotive*. The explosion motor is frequently called the internal-combustion motor.

**Q. Is there anything strange or mysterious about this source of power?**

A. No. It works very much the same as a steam engine, except that the expansion of ignited gasoline vapor which has been highly compressed is used instead of the expansion of steam.

**Q. What is a cycle?**

A. A cycle consists of a series of steps or successive actions, which, taken together, complete the working of the unit. In the case of an engine the cycle is the number of successive operations through which it goes in order to run continuously.

**Q. What is the cycle of an explosion motor?**

A. The cycle of the explosion motor consists of five parts: (1) the suction, or admission of mixture; (2) the compression of this mixture; (3) its ignition, or explosion, when compressed; (4) its expansion subsequent to explosion; and (5) the exhaust, or expulsion of burned gases after expansion.

**Q. Do these four steps always take place at the same time?**

A. No. There are two general types of engines, those in which the cycle is completed in four strokes and those in which it is completed in two. The former are called four-stroke cycle engines, generally abbreviated to four-cycle, and the latter two-stroke cycle engines, usually spoken of as two-cycle. The former are also quite often spoken of as Otto-cycle engines because of the pioneer Otto who developed this type.

**Q. Are there other than these two arrangements of the cycle?**

A. Yes. Engines have been built to operate on a six-stroke cycle, the two extra strokes being used to draw in cold air and thus keep the engine cool, with the primary idea of dispensing with water-cooling apparatus. In addition, other cycles have been proposed from time to time by inventors. But the two- and four-cycle engines are the only successful ones.

**Q. What is the generally accepted type of automobile motor?**

A. Automobile motors are, as a rule, multi-cylinder four-cycle vertical forms, designed to run at 800 to 900 r.p.m., or higher, with long strokes, magneto ignition, four or more mechanically operated valves, using gasoline as fuel, and having speed control by means of spark and throttle levers and foot accelerator. The vertical four-cylinder and six-cylinder are the most popular forms, although a considerable number of eight- and twelve-cylinder V-type or inclined-cylinder engines are now being built. Practically all automobile engines now have two or more mechanically operated valves per cylinder, the latest development being the use of four valves per cylinder. By long stroke is meant a longer stroke than the bore, generally longer in the ratio of 1.1 (or higher) to 1.

**Q. What is standard practice in cylinder arrangement?**

A. The two most popular cylinder arrangements are those in which the cylinders are cast in pairs, and those in which they are cast in a block, or single unit. The latter is gaining way rapidly, its simplicity and compactness being big arguments in its favor.

**Q. What is the usual practice in valve arrangements?**

A. With two valves per cylinder, there are three general arrangements and one combination form. These are: (1) both valves on one side; (2) one valve on each side; and (3) both valves in the cylinder head. The combination arrangement is one valve on one side and one in the head, usually directly over the other.

**Q. Do these valve arrangements change the type of cylinder?**

A. The cylinder form is ordinarily named from the valve arrangement or from the shape of the combustion, or explosion, chamber which this arrangement brings about. Thus, the type where both valves are on one side of the cylinder is called an L-head, because the combustion chamber has the shape of an inverted letter L with the valves in the projecting arm. When the valves are on opposite sides of the cylinder, it is called a T-head cylinder because the combustion chamber has the shape of a letter T with one valve in each branch of the top. When the valves are both in the head, the cylinder is called an I-head, or valve-in-the-head. The form in which one valve is in the side and one in the head, is called an L-head also because the combustion chamber has an L-shape.

**Q. What is the Knight, or sleeve-valve, motor?**

A. A motor similar in appearance to other motors but having, instead of the usual poppet valves, a pair of sliding sleeves which have openings, or ports, through them. By the operation of these sleeves up and down, the inlet and exhaust ports are opened and closed in a manner similar to the ordinary poppet valves.

**Q. How is this action brought about?**

A. The two sleeves are cylindrical, and fit between the cylinder and the piston. Both have holes, or ports, on the two sides, corresponding to the valves on opposite sides of a T-head motor. The sleeves are moved up and down by rods attached to eccentrics operated by an eccentric shaft. When the movements of the two sleeves bring together the inlet ports and bring these into register with the port in the cylinder walls on the inlet side, the inlet opening is completed and the piston draws in its mixture. Similarly, when the ports in the two sleeves and that on the other side of the cylinder register, the exhaust opening is completed, and the burned gases are forced out. At other times, the ports do not register and the cylinder is practically sealed, this being the case on the compression and expansion strokes.

**Q. In what way is this an advantage?**

A. The valve timing always remains the same, never varying with time, wear, lack of care, or anything else, which is not true of poppet valves. Again, the movement of the sleeves can be such as to give a quicker opening and quicker closing; that is, it can produce a wide-open port more quickly, and close from a wide-open port to no

opening at all more quickly than the poppet form, because the sleeves do not move up and down together. They can be made to move in opposite directions so that a port is opened or closed with double the usual speed. There is no possibility of leakage of gases either by time, wear, lack of care, or other factors. All of these things make for a larger and a more regular power output throughout the motor's life.

**Q. What is the usual form of motorcycle engine?**

A. Usually the motorcycle is a one-cylinder vertical, or two-cylinder V-type air-cooled engine, although a few four-cylinder vertical air-cooled ones have been built and are still being turned out. All these are of the four-cycle form except the Shickel which is two-cycle.

**Q. What is the firing arrangement of explosion motors?**

A. The firing arrangement varies with the number of cylinders and in engines of the same number of cylinders, varies with the form of the crankshaft, and often varies in similar crankshafts.

**Q. What is the general two-cylinder firing arrangement?**

A. Two-cylinder motors with the cranks set at 180° (that is, the horizontal opposed form like the Autocar commercial car) fire one-half revolution apart, so that they have two power strokes on one revolution and none on the next.

**Q. How does the engine continue to run with an arrangement like this?**

A. After the first explosion, the flywheel supplies the power necessary to carry the engine over the idle strokes, in fact this is the function of the flywheel—to store up energy or rotation on the firing or explosion strokes and give this back on the idle, or suction, compression and exhaust strokes.

**Q. What other two-cylinder firing arrangement is used?**

A. That in which the cranks are set at 360°, or in the same position. In this form, there is an explosion each revolution, but excessive vibration results from all the parts working in the same direction all the time. That is, both pistons go down together, then both go up, etc. The evenness of firing is overbalanced by its excessive vibration.

**Q. What is the usual four-cylinder firing arrangement?**

A. As a rule the cranks are at 180° in pairs, cylinders 1 and 4 being together, and cylinders 2 and 3. This allows of two very similar firing arrangements, as 1-3-4-2, or 1-2-4-3. There is little choice between them, although the first is more popular.

**Q. What is the general six-cylinder firing arrangement?**

A. Usually, the cranks are set at 120° apart in pairs, 1 and 6 acting together, 2 and 5, and 3 and 4. The firing can be any combination of these in which the first comes from one group, the second from another, the third from a third, then the fourth, fifth, and sixth come from the remaining member of each group in the same order. Thus, 1-5-3-6-2-4, or 1-5-4-6-2-3, or 1-2-3-6-5-4, or 1-2-4-6-5-3.

**Q. What is the usual eight-cylinder firing arrangement?**

A. The eight-cylinder firing is always the firing that a single group of four cylinders on one side would have with that same form of crankshaft, and this firing order is applied first to one side and then to the other. Thus a typical four-cylinder firing order of 1-3-4-2 applied to an eight-cylinder, similarly arranged, would be 1R-4L-3R-2L-4R-1L-2R-3L. If these are repeated a second time it will be seen that the 1-3-4-2 order follows out on both sides, only one starts in later, and the two alternate from right to left, thereafter.

**Q. What is the theory of crank effort?**

A. Only one of the four strokes of the motor is a productive one, and not all of that, so in the one-cylinder engine 20 per cent of the cycle must produce all the power. In the two-cylinder this is increased to 40 per cent, in the four-cylinder to 80 per cent, and in the six-cylinder to 120 per cent. This last indicates the overlap at various points, for the cycle like anything else can never have more than 100 per cent power. In the eight-cylinder it is 160 per cent, and in the twelve-cylinder 240 per cent, indicating the relatively greater overlap, and consequent smoother running.

**Q. How does the average small two-cycle motor work?**

A. The mixture is admitted to the crankcase, which is built very close to the revolving parts, and in this way the downward movement of the piston compresses somewhat the charge in the crankcase. At a certain point in the downward movement of the piston an opening through it registers with a by-pass which leads up into the combustion chamber with suction inlet valve. Thus the single downward stroke of the piston compresses the charge and fills the cylinder with it. This gas really flows in at the end of the combination power and exhaust stroke, but as the exhaust port is at the bottom of the cylinder, little or none of the incoming gases flow out through it. On the return of the piston, the gas is compressed, and at

the end of that stroke when the piston is ready to descend, is ignited and expands. Just before the end of this power stroke, the exhaust port is uncovered and, being rather large, the exhaust gases flow out very quickly, the entire cylinder being emptied in a very short portion of the stroke. Consequently, when the end of the power stroke is reached, the exhaust also has been completed. In this way, the entire cycle is performed in two strokes of the piston.

**Q. What are the disadvantages of this?**

A. The preliminary compression is not sufficient to force in a full charge, nor is the suction strong enough to hold open the suction-operated valve and draw in a full charge at the same time. Consequently, the inlet, or suction stroke, is seldom efficient. Further, not all of the exhaust gas is removed, the balance remaining to dilute, or offset, fresh gas, thus further lowering the suction or charging efficiency. If the exhaust port is so made as to give a good full-cylinder charge, some of the incoming gas is likely to sweep over and out with the exhaust, thus being wasted. Either arrangement gives an inefficient exhaust; for with the one, exhausting is not complete, with the other, the power part of the stroke is cut down. The result is that instead of giving double the power from a given size of cylinder as compared with a four-cycle engine, the relative output is about $1\frac{1}{3}$ times the four-cycle of equal size.

**Q. How is this form sometimes varied?**

A. By adding an automatic inlet valve to the crankcase and eliminating the suction-operated valve in the cylinder head. This also shortens and simplifies the by-pass. The exhaust is made to open a little earlier than the suction connection to the cylinder, and the piston is made with a projecting lip to deflect the incoming fresh gases upward while the exhaust gases are flowing downward. This method reduces the dilution of the incoming charge and the losses of fresh gas flowing out of the exhaust opening, and the engine is made more simple and slightly more efficient.

**Q. What general disadvantages render two-cycle engines unsuitable for automobile and motor-truck work?**

A. The two-cycle engine will not throttle down, so as to run slowly, but must be kept turning at a fairly high rate of speed. This is a double disadvantage when the car or truck is standing idle at the curb, as it makes a noisy engine and uses much fuel. In addition, the

engine will not run at very high speeds, its normal maximum being close to or below 1500. This means a small gear reduction to give fair speed in the average car, and that in turn raises the lower speeds too much, or else complicates the gear box. Further, the two-cycle motor does not respond well to sudden changes of speed.

**Q. Is there any work for which these are not disqualifying conditions?**

A. Yes. On the motorboat, particularly on the smaller sizes. In a motorboat, after starting, the speed is generally continuous and even; there are no sudden spurts, no slowing down, no speed changing. For this all-day running at constant speeds the two-cycle motor is quite suitable. In addition, it is a very low-priced motor to build, and as the smaller motorboats must be sold at an extremely low price, it is quite suitable. The fact that it has no parts which can be changed or adjusted renders it quite suitable to the unmechanical class which buys this form of boat. However, even for this kind of work, it seems to be going out of favor.

**Q. How is the power of a gas engine measured?**

A. In one of two ways, theoretically on the indicator or manograph, or actually by means of the dynamometer or Prony brake.

**Q. Is there more than one way of indicating this power?**

A. Yes. The indicator similar to steam engine indicators makes a permanent diagram which can be removed and preserved; but this form is not entirely suitable to the high speeds often obtained in automobile engines. The manograph overcomes all speed disadvantages but does not make a permanent card; it simply shows the average card while running as a moving beam of light. This is convenient in some ways but inconvenient in others.

**Q. Are there several ways of measuring actual power?**

A. Yes. The dynamometer gives its measure in electrical units, which in well-designed apparatus, can be read off directly on the electrical instruments. The Prony brake gives a measure of the power output in weight on the scales which the engine will support, and by figures the power output can be worked out from this.

**Q. What is the mechanical efficiency of an engine?**

A. The proportion of the power which the engine should give, as measured by the indicated horsepower, to that which is actually given, as measured by the brake horsepower (either Prony or electrical

dynamometer). By dividing what the engine gives by what the indicator card says it should give, a figure is obtained for the mechanical efficiency.

**Q. What is the usual horsepower formula now in use?**

A. All automobile engines in this country, England, and many other foreign countries, are rated by means of the formula which was originated by the Royal Automobile Club of England, adopted by the Association of Licensed Automobile Manufacturers, then by its successor, the National Automobile Chamber of Commerce, and, finally, by the Society of Automobile Engineers. Its form is

$$\text{h.p.} = \frac{D^2 N}{2.5}$$

in which $D$ is the bore of the cylinders, $N$ the number of cylinders, and 2.5 a constant worked out from tests on a number of automobile engines. In other words, to find the rating horsepower of a motor, square its bore, multiply by the number of cylinders, and divide by 2.5.

**MITCHELL "SIX OF '16"—A FIVE-PASSENGER TOURING CAR**

*Courtesy of Mitchell-Lewis Motor Company, Racine, Wisconsin*

# BUILDING, EQUIPPING, AND RUNNING A PUBLIC GARAGE

## PRELIMINARY PROBLEMS

### RANGE OF BUSINESS

**Service of Public Garage.** During the years of development of the automobile, the problems of its care have been solved with equal precision. The automobile mechanic has become skilled in his line, so that the repair shops, which are almost invariably a part of a public garage, render valuable service in curing the aches and pains which every car develops at some time or another. The system of garage service, too, has become standardized; but a point that is appreciated all too little in the business is that a garage is essentially a service proposition. A man takes his car to the garage to be cared for and pays the charges for this to relieve himself of this work. Many men patronize a public garage because they do not want the work of washing, cleaning, and oiling their cars; many others go there because they lack mechanical knowledge and prefer to pay for this knowledge and the service which goes with it, in the way of adjustments, replacements, and general care, rather than to try to learn these things themselves.

Viewed from this standpoint, the garage is nothing but a service proposition, rendering service which the public would rather pay for than to carry out itself. No man should go into the garage business with any other thought than to render the utmost of service and to charge a fair price for it. Many garages have been unsuccessful in the past because their owners lacked an understanding of this principle, the businesses having been run with the idea of rendering as little service as possible and getting as much money as possible for it; in short, the garage business has been reduced to a housing proposition, that is, payment for floor space and a roof to protect the cars from the weather. Another phase of this question is that many garages have been unsuccessful in the past simply because they rendered services of value without making an adequate charge

for it. The garage can no more afford to give away its product—services and work—than can the butcher or baker afford to give away his produce. Similarly, when the garage takes on the sale of the most needed accessories as a side line, it cannot afford to give these away even in the smallest quantities. Therefore, no one should go into the garage business unless thoroughly imbued with the idea of selling service and getting as well paid for the service rendered as is legitimate. Moreover, this thought should be prominent from the start, so that the building can be planned and built with facilities for rendering this service the most quickly and easily, and with the least cost to the management.

**Selling Cars as a Side Line.** The question of whether it is advisable and profitable to sell cars as a side line and whether it works in well with the garage business is one that depends upon the place where the garage is located and also upon the man. There undoubtedly are situations in the country or in the small town where this combination is a nautral and desirable one, because the business will be small enough to make it almost necessary to concentrate everything—sale of cars and of accessories, and the care and repair of both after the sale—in a single building and under one management. As a rule, however, it has been found that the two lines are separate businesses and require separate and distinct methods of handling. The men fitted for one business are seldom, if ever, suited to the other, and the nature of the buildings—its fittings or surroundings, equipment, care, heating, lighting, and many other things—is so different as to warrant separating the two; in short, it is very seldom that the garage and the salesroom can be operated together to advantage.

**Selling Accessories.** The secondary question of whether it is advisable to go into the sale of accessories must also be considered. It might almost be taken for granted that the garage would sell oil, grease, and other lubricants; gasoline, kerosene, and other oil products; but in the matter of the smaller but frequently used accessories, such as spark plugs, tire-repair kits, jacks, and other small tools, tires, and similar supplies which are in constant demand, local conditions outside of the garage usually govern.

In the country or in the small town, where automobile accessories and supplies are not handled by any other stores, it is advisable for

the garage builder to consider this point and to provide space and a suitable arrangement for handling them.

In the city, on the other hand, there are many stores that handle accessories on a scale far beyond the ability of the garage man. This enables the big stores to give a choice in the way of quality and price that puts the garage man at a disadvantage. To sum up the matter, where the number of people, and, as a result, the number of cars and trucks, within a reasonable radius of the garage is great, there will be stores specializing in supplies and equipment; and it is inadvisable for the garage man to go into their sale on as large a scale as capital and business in sight will permit.

**Special Side Lines.** Practically the same conclusions apply to the matter of including the auxiliary business. By side lines, reference is had to vulcanizing and tire repairs; to painting, upholstering, and top work; to general machine shop work and alterations on a large scale, such as the remodeling of old cars, the conversion of cars into trucks, etc.; complete overhauling which necessitates facilities and equipment beyond the average garage; and other things. In the country and the small town, it is advisable to go into these various auxiliaries as far as the business in sight will warrant, but in the cities where there are specialists in these lines who can give more and better service, give it quickly and advantageously, and perhaps at a lower price with profit, it is inadvisable, and the garage man should not attempt anything outside of strictly garage service.

In the medium size town, it is frequently advisable to consider the general proposition of having a number of such auxiliary businesses in the same building, apparently component parts of the garage, but, in reality, separate and distinct firms, each run by a different man. This makes a convenient working unit for the people owning cars, yet the various businesses being separate, and each run to facilitate a special line of work or endeavor, they do not conflict; on the contrary, each one derives business from its close association with the others.

**Financial Problems.** One point which should be considered with more care than any other is the matter of financing. It is a big mistake to start a garage on the assumption that it will pay a profit from the start. This is seldom the case, and the prospective garage man should plan his finances so that he will have sufficient

money to care for running expenses for a considerable length time. This should be done even if the initial building is not built large as the garage man plans to have it ultimately, and even if tl equipment is not as complete as might seem desirable. In a ve short time, if the garage has been planned wisely, the location chos carefully, and if the business is run on a basis which holds all boarde who come in and attracts more, the profits will come, and the exte sions of building and equipment can follow.

## CHOOSING THE LOCATION

Probably no single item will have a greater influence on th success or failure of the garage business than the wise choice c location. Three things must be considered: existing car owner the location and proximity to main highways, and the allowabl size and shape of the building. The value of the land will have a influence on the overhead expense, for what might seem an idea location in every other way may be beyond the financial means o the garage man.

**Land Values and Size of Building.** Size is closely inter-relatec to value of land and to the cost of the building, as will be showr by a simple example. If a plot 80 x 100 can be arranged to such advantage as to hold the same number of cars as another plot 100 x 100, and the former cost but $8000, while the latter is held at $10,000, other things being equal, the first is the best business proposition. Suppose both plots will hold 56 cars; then the land cost alone is $143 per car for the first lot and $178 per car for the second. Obviously, a greater price would have to be charged for storage in the second case than in the first, to make an equal margin of profit. And what is true of the land is equally true of the building, for a building 100 x 100 would cost at least 15 per cent more than a similar one which measured only 80 x 100.

**Central Location in Territory Desirable.** In choosing a site there are two points to consider. Generally speaking, that site in the proposed territory would be best which is in the geographical center of the cars that would use it. This could be arrived at mathematically, of course, but this is unnecessary, because a rough inventory of the cars upon which the garage would depend for patronage will locate a general center of action that is satisfactory.

If the surrounding residents protested against a garage at the cation decided upon, or if there were any other reasons why it ould not be located in the place desired, a second item would have s influence upon the second best choice. This is the proximity a through highway. The importance of this point may be judged om the plain statement that many garages, during the touring eason, derive more than 25 per cent of their receipts from passing ars. The transient trade grows more important each year as touring ncreases. The influence of this growth would be such that when he second choice has to be made outside of the center of action of he territory to be served, this location should be such as to bring he garage nearer, as much nearer as practicable to the point where t can retain the permanent trade and still get that of the through highway.

## DETERMINING SIZE OF GARAGE

**Methods of Calculating Size.** The inventory of the proposed territory is valuable, since it gives a good basis for the size of the garage. Obviously, in a territory with but 25 cars all told, of which perhaps 15 were well housed in private garages, it would be foolish to build for more than 30 to 40 cars, that is, the 10 to start with, perhaps as many added in the first year because of the presence of the garage, and an average of 4 or 5 transients would be about all that could be counted on throughout the first year. This totals less than 25 cars on the average, and a building large enough to house 30 to 35 cars is all that this much business would warrant. Of course, a small quantity of oils, gas, and minor supplies would be sold to the owners of the other cars, but the profit from these would be very small because the sum total of the sales would be small. Transient trade bulks up large, by comparison with steady boarders, principally because it is almost universally charged about twice as much, that is, a garage having a flat monthly rate of $15 a month, will charge all transients $1 a day, or $30 a month, making one transient, while it stays, the equal of two steady boarders. The boarders, however, form the backbone of the business, since without them the garage could not exist to take the transient trade.

Knowing the number of cars available and estimating the additions and the average number of transients during the first year,

a rough total can be arrived at which can be used to determine the size of the building. An average car must have a floor space of approximately 15 x 7, and at least 20 feet should be allowed for a comfortable aisle, or driveway, between standing cars. Few cars, if any, actually total 15 feet in length, or 7 feet in width, but, on the other hand, cars cannot be placed in the space assigned within a few inches; so the space given is about as small as can be used.

**Methods of Arranging Cars.** The size of car and of the aisle space brings out our first rule of garage proportioning, in which there are three ways of arranging cars: one row on each side of a central aisle; two rows deep on one side, and one row on the other side of a central aisle; two rows deep on each side of the aisle; also duplications of these arrangements when the garage is unusually wide. Taking the figures given above, we get the following preferred widths, namely, two 15-foot spaces and a 20-foot aisle for the first case, or a 50-foot total; three 15-foot spaces and a 20-foot aisle in the second, or a 65-foot total; and four 15-foot spaces and a 20-foot aisle in the third, or an 80-foot total. Doubling up on these gives 100 feet for the first, 130 feet for the second, and 160 feet for the third. This last is probably too wide for all normal conditions, but the other five are possibilities.

To make these more clear, Fig. 1, in which these five cases are shown, respectively, at *A*, *B*, *C*, *D*, and *E*, is presented. The depth needed per car is 7 feet; so the width having been determined, and one of the above five methods having been fixed upon as the best for the purpose, the total depth is found by dividing the number of cars to be housed by the number accommodated in one 7-foot width, and then multiplying this result by 7. Thus, suppose a narrow garage has been fixed upon, under scheme *B*, Fig. 1, which accommodates three cars in one width, or 7 feet. And suppose the total number of cars to be provided for is 90; then 3 goes into 90 30 times, and 30 times 7 gives 210 feet for the total depth. As this is deeper than lots usually run, it would be best to change to scheme *C*, which accommodates 4 cars per strip of width, thus 4 goes into 90 22 plus, and 22 times 7 equals 154 feet for the depth. Under certain conditions, a strip might be available straight through the block, so that instead of changing to scheme *C* we could go the other way, changing to *A* and making the garage narrower and longer.

On this basis, 90 cars would need a strip 50 x 315 feet. The advantage of the last method would be to provide two entrances, one on each street.

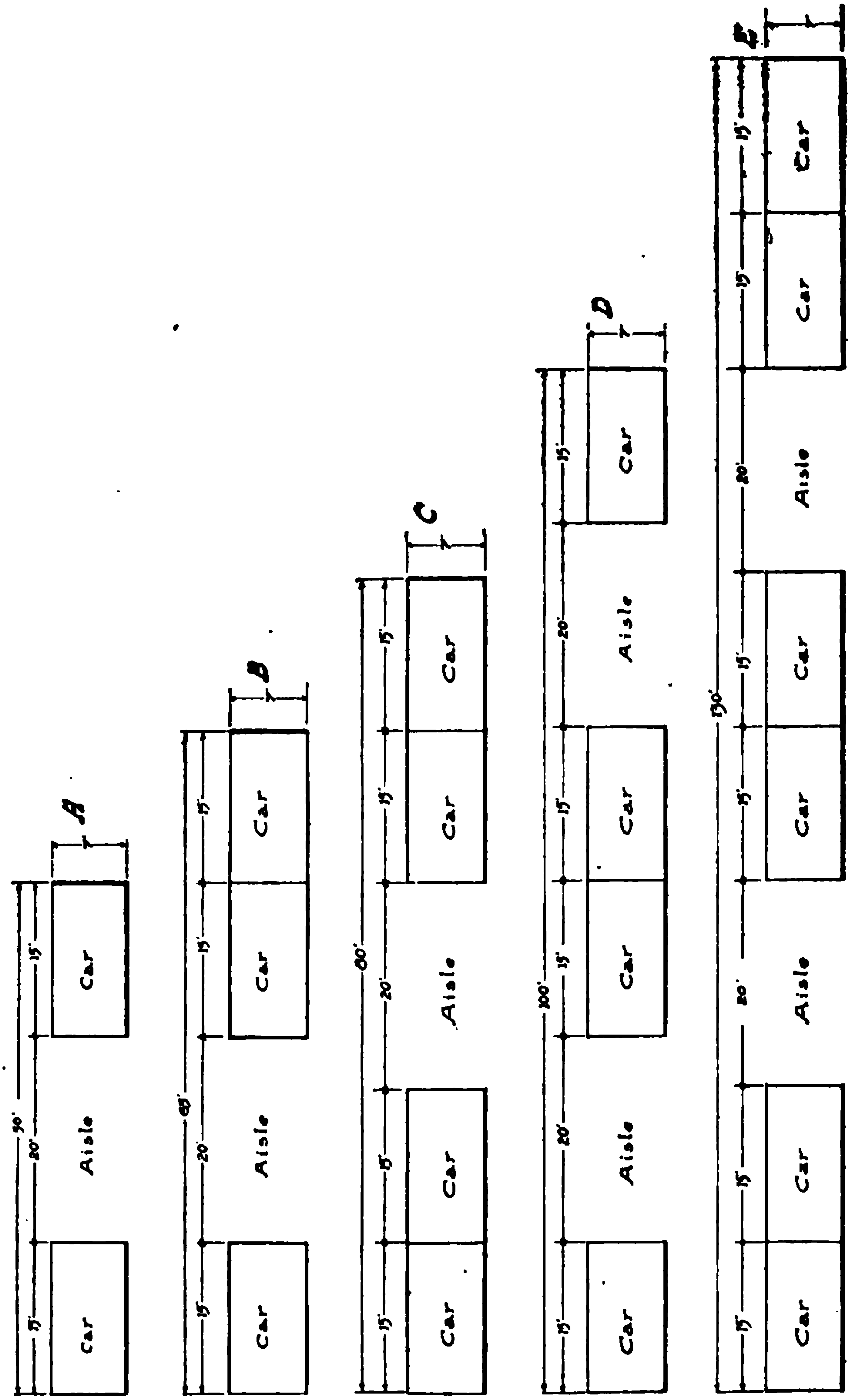



Fig. 1. Various Possible Arrangements for Garage Interiors

The writer has seen cars placed in a garage parallel to the aisle, as sketched in Fig. 2. This placing has the disadvantage of making

much extra work in putting in or taking out a car behind those in the front row. Usually, where the cars all face in one general north and south or east and west direction, there is little trouble in getting a car in or out, except at the times when all owners come in or go out at once. But as soon as a different placing is introduced, there is difficulty, for not only must more cars be moved, but they must be moved in different directions, and some of those moved will obstruct the passage of the car coming in or going out, thus making double work. This method, however, is usable; in fact, it is in fairly wide use. It increases the width in scheme *A* to about 57 or, in round figures, 60 feet, and adds one car in each two strips for every 14 feet. In *B* it makes the width 72 or, in round figures, 75

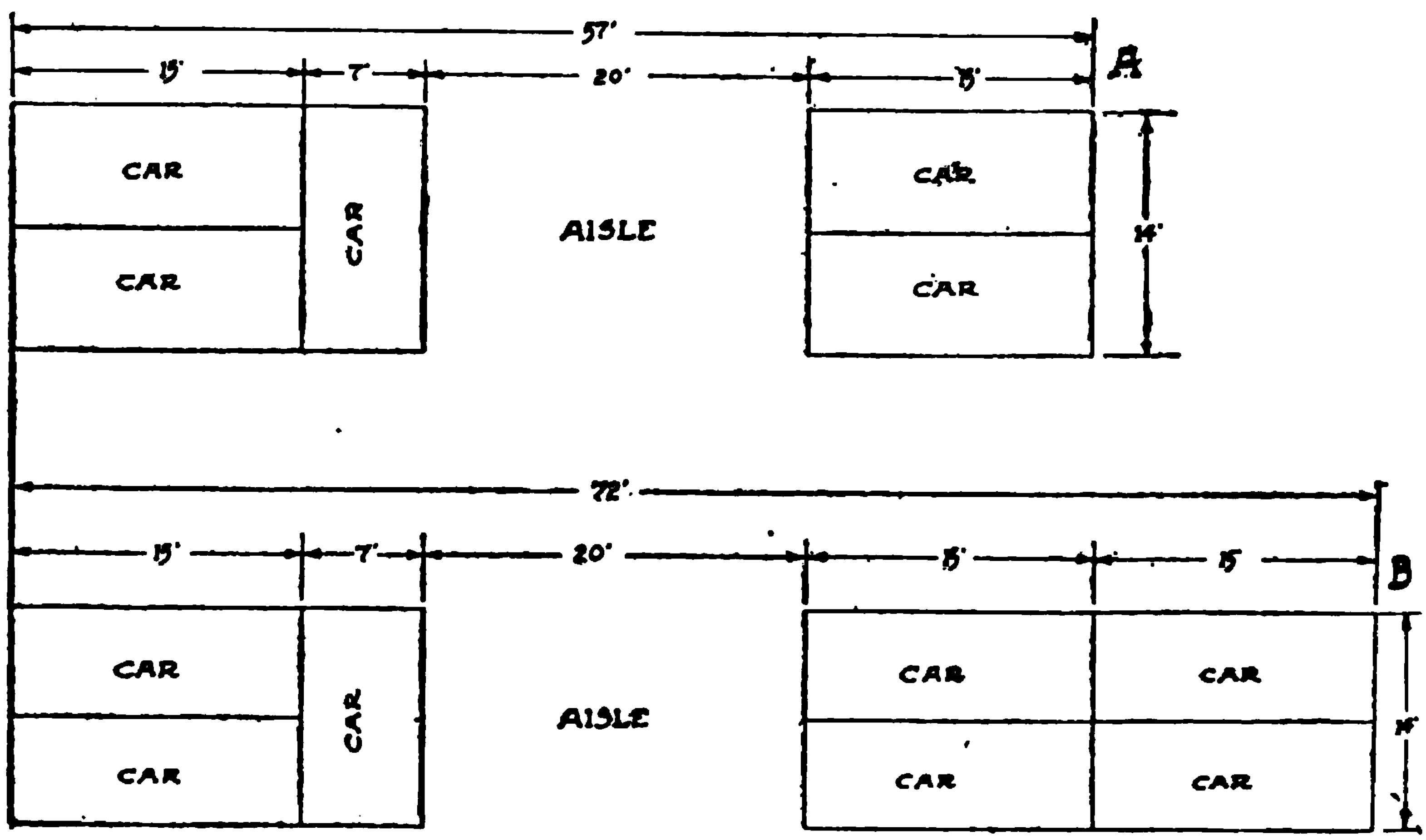



Fig. 2. Modifications of the Garage Arrangements of Fig. 1, Made Possible by Turning Part of the Cars

feet, and adds one car for every 14 feet of depth. In *C* it makes the width 87 or, in round figures, 90 feet, and adds one car for each 14 feet, or adds two—one on each side—when it is 95 feet in width. Schemes *D* and *E* may be handled in a like manner.

**Modifications of Size Due to Situation.** If the garage is situated in a small town or in the country, it is possible to slightly trim the dimensions given. Thus, a Ford car needs but 12 feet; being uniformly narrower and turning shorter than other cars, it can be handled in a narrower aisle. This would mean that a garage entirely for Fords could have, under scheme *A*, Fig. 1, a width as little as 12 + 15 + 12, or 39 or, in round figures, 40 feet. This is an unusual supposition,

but is given to show how valuable the inventory of the territory is and how complete it should be, for this inventory would show the relative number of small machines.

**Other Modifications and Deductions.** *Space for Office Fuels, Etc.* In what has been said previously, the entire inside of the building has been figured as storage space and aisles for cars. This is not ordinarily possible, for there are many other things to consider, all of which deduct from the interior space. First, there is the office which must be well and wisely located, for it must govern the incoming and outgoing in such a way as to keep a perfect check on all cars. Then there is the room, preferably separate from the office, for the oils, fuels, and greases. Usually, the building regulations require a fire wall all around this room, and, even if they did not, it is good policy to build it that way. Then, the wash rack is a very important place and takes up the space of at least two cars, possibly more. Toilet rooms for both sexes, lockers, air compressor, and other things require floor space. Also, if there is a sales department connected with the garage, either for small things or for the larger units, as tires, a show room and storage space are both needed. Then, too, there is the matter of auxiliaries. If the shop has a tire-repair department, space must be allowed for this. Similarly, if any of the other auxiliaries are included, they deduct from the floor space for car storage.

*Space for Stairways and Elevators.* If the building is more than one story high, the space taken up by the elevator and immediately surrounding it on all floors, or that taken up by ramps, or inclines, if they are used, must be considered. This space might be thought to be small at first, but, in figuring it over, it will be found that the elevator must be at least 16 x 8 in size, which means at least an 18 x 10 total. To this space must be added at least 10 x 10 for the machinery to operate it, and approximately as much more, 10 x 10, which must be kept clear at the elevator in order to give access to it readily. This space totals 38 x 10, a space almost equal to four cars, which should be deducted on each floor, while ramps would take out still more space.

*Space for Posts.* In order to support the roof or upper floors, as the case may be, posts or expensive structural steel trusses are necessary. The location of these posts influences the arrangement of

the cars, both as to width and as to depth, so that unless they are very cleverly placed much space can be lost around them. In a comparatively large garage of considerable width where more than one row of posts is needed, the space taken up by posts mounts up considerably, and can easily total that of two or three cars.

*Summary of Deductions.* By the time the space of two cars is allowed for the office, that of two more for toilets, one for lockers, one for the fuel and oil room, that of two or three more for the wash rack or twice this amount if there are two wash racks, that of one or two for the posts, etc., and the total added up, it is found that a fairly large percentage of the storage space is gone. If the building be one with upper floors, it is found that elevators or ramps have taken out fully as much more, and that all this deduction is repeated on each floor, with the exception of the office space and of the fuel and the oil spaces.

All the modifications and deductions stated in the preceding paragraph must be taken into account in laying out the original plans and in buying the site and erecting the building. If the net floor space which can store cars, and the number of cars which can be stored in this space be multiplied by the average price which can be obtained for each space, the answer will, to a great extent, determine the revenue. Consequently, if the deductions reduce the space below the point previously considered necessary, the size should be increased to compensate for this loss, that is, if deductions cut out 10 cars that were figured in, the size should be increased sufficiently to house 10 more cars than were provided for originally.

The plans for four different sizes of garage will be considered in detail. These plans are not offered as ideal, for such a thing as an ideal garage does not exist, but they will present, in a more easily grasped form, some of the difficulties of garage planning and construction. The sizes have been selected upon the basis of being: small; medium size; large; very large.

Except for the very large size, which is too large for any but city use, these garages might be located anywhere. After the garages have been considered in detail, the matter of equipment will be taken up, and the equipment that is generally considered necessary will be indicated; also the equipment that is desirable and perhaps profitable but not necessary, as well as that which the handy garage

man can make for himself; most of the latter equipment is also desirable and profitable, but it is not absolutely necessary. Finally, such other details as heating, ventilating, safety, lighting, cleanliness, and other similar subjects will be considered according to their value.

## DESIGNS OF PUBLIC GARAGES

### SMALL SIZE GARAGE

While it might be considered small in the country, or in a very small city or town, a garage approximately 50 x 100 is generally spoken of and considered as a small garage. Such a garage can seldom be arranged to regularly care for more than 25 cars and take care

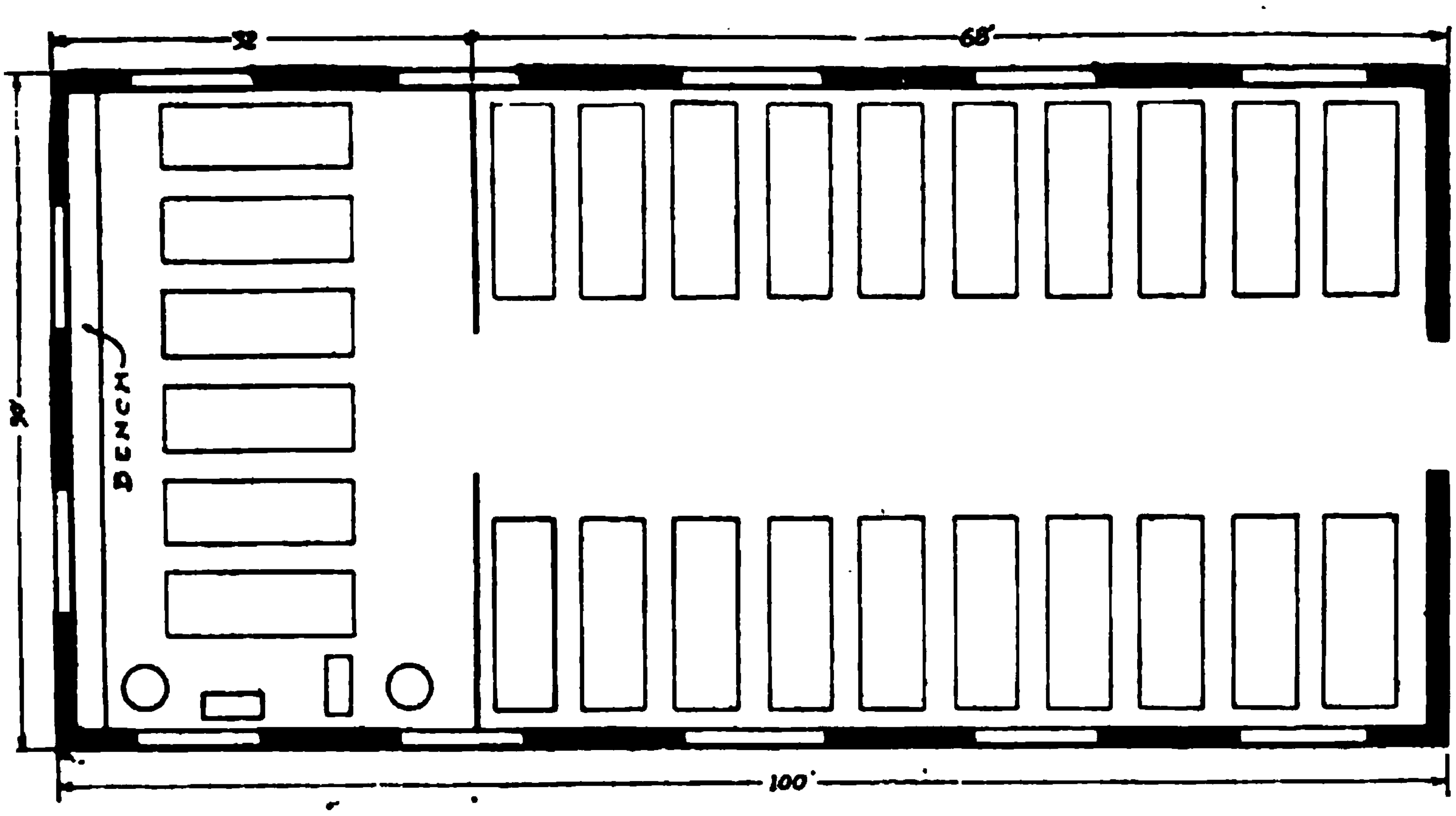



Fig. 3. Average Arrangement of Small Garage (50 x 100) to House 27 Cars

of them well. If any accessories are sold, the space they occupy cuts down the number of cars. If an agency for a car or a truck is maintained, space must be provided for a show room and salesroom, and a building of this size can seldom be used to store as many as 20 cars. Although it may seem large, it is, in reality, small.

**Typical Arrangements.** *Layout 1.* Let us see how this space can be arranged to the best advantage. In Fig. 3 is shown a layout in which the cars are arranged along the two walls at the front part of a 50 x 100 building, but the last 32 feet of this space have been partitioned off into a form of repair shop, with a bench along the rear wall and a few tools in one corner. This layout provides no office and no locker space, but just the bare storage room, with a

little space for repair work, and few facilities for doing it. It accommodates 26 cars, as the sketch shows.

*Layout 2.* If the intention was to have storage space only, with simply a bench provided for repair work, this space could be managed more advantageously by rearranging it, as shown in Fig. 4. Here the partition has been taken out, and for a short distance along one wall all cars have been moved out into the central aisle a few feet. This allows room for the work bench and space beside it in which to do work. Space is provided for 28 cars, 2 more than in layout 1, and, if it were necessary, two cars could be put against the rear wall in the aisle, as shown by the dotted lines, to make a total of 30. Of course, the corner for tools and the tools themselves

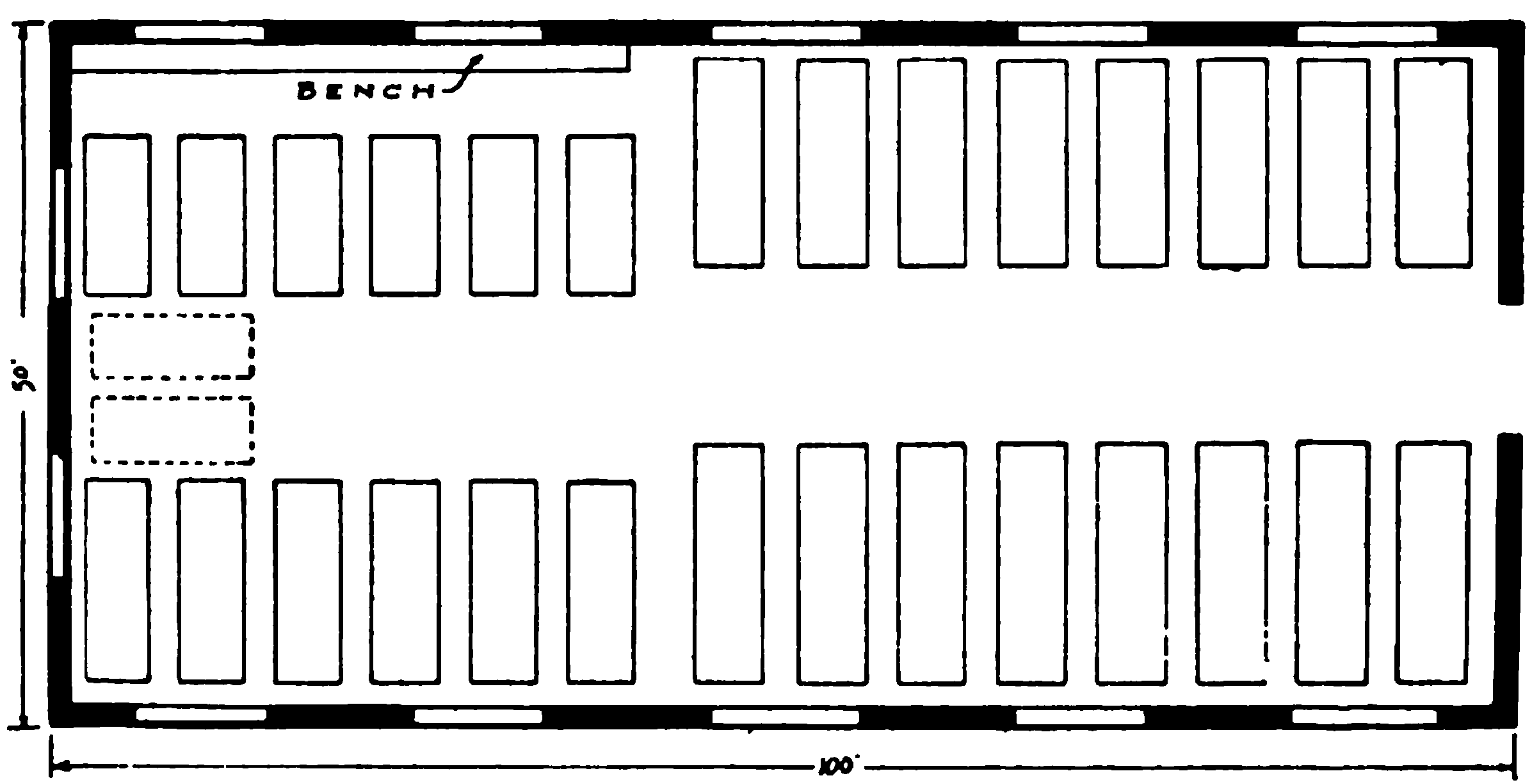



Fig. 4. Rearrangement of Small Garage to Hold 28 (and possibly 30) Cars

have been taken out, but, aside from that, the rearrangement has added almost 16 per cent to the revenue.

*Layout 3.* This is perhaps the maximum space for this size of garage, as nothing but storage space has been provided. If a wash rack is to be added, that will cut the storage space down. So, too, will an office for accessories and a show room. Another arrangement is shown in Fig. 5, in which the entire front of the building is given up to display, the cars entering at the rear. Note how the show room takes the larger part of the front, and the accessory salesroom the other part; also how the offices, toilet rooms, and stock room take up space back of the salesroom, so that the garage itself houses but 19 cars. The wash rack is really in the aisle, although at one end.

*Layout 4.* By eliminating the private office, or rather combining it with the other office, with a door opening into both the show room and the accessory salesroom, and by leaving out the toilets, as indicated in Fig. 6, which is this same plan revised, 5 cars may be added to

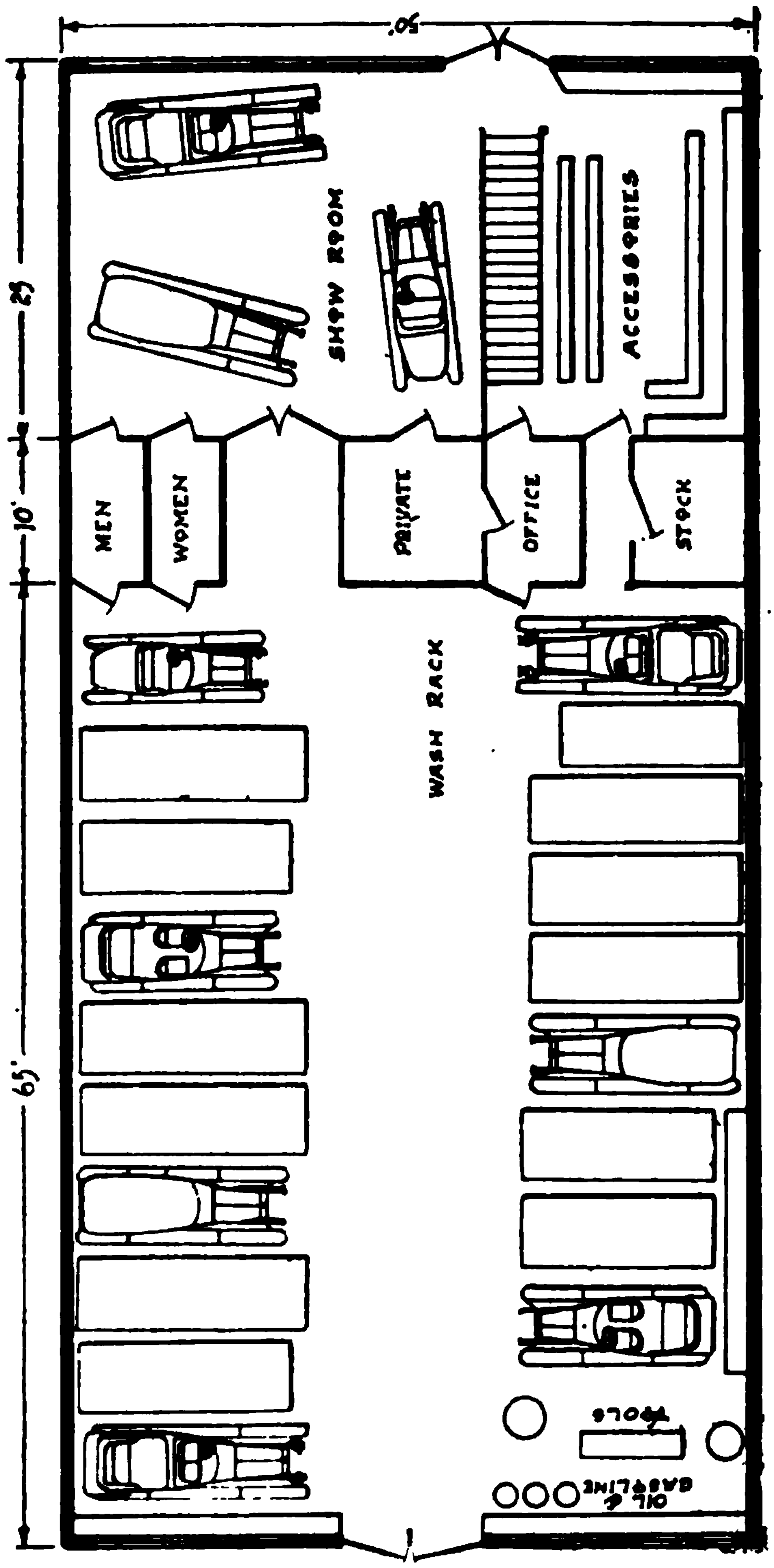


Fig. 5. Another 50 x 100 Garage Arrangement Which Provides Show-Room Space

the storage total, making 24 in all. This arrangement would be particularly good if the shop walls of the central office were of glass, for then it would be possible for a person in the office to keep track of the entire establishment—show room, accessory salesroom, and garage. This layout provides for oil and gasoline storage, tools,

**work bench, wash rack, salesroom, accessory room, stock room, and office, yet it houses 24 cars.**

***Layout 5.*** **Another 50 x 100 floor plan is shown in Fig. 7. This plan provides for the grouping in one unit, on the right side**

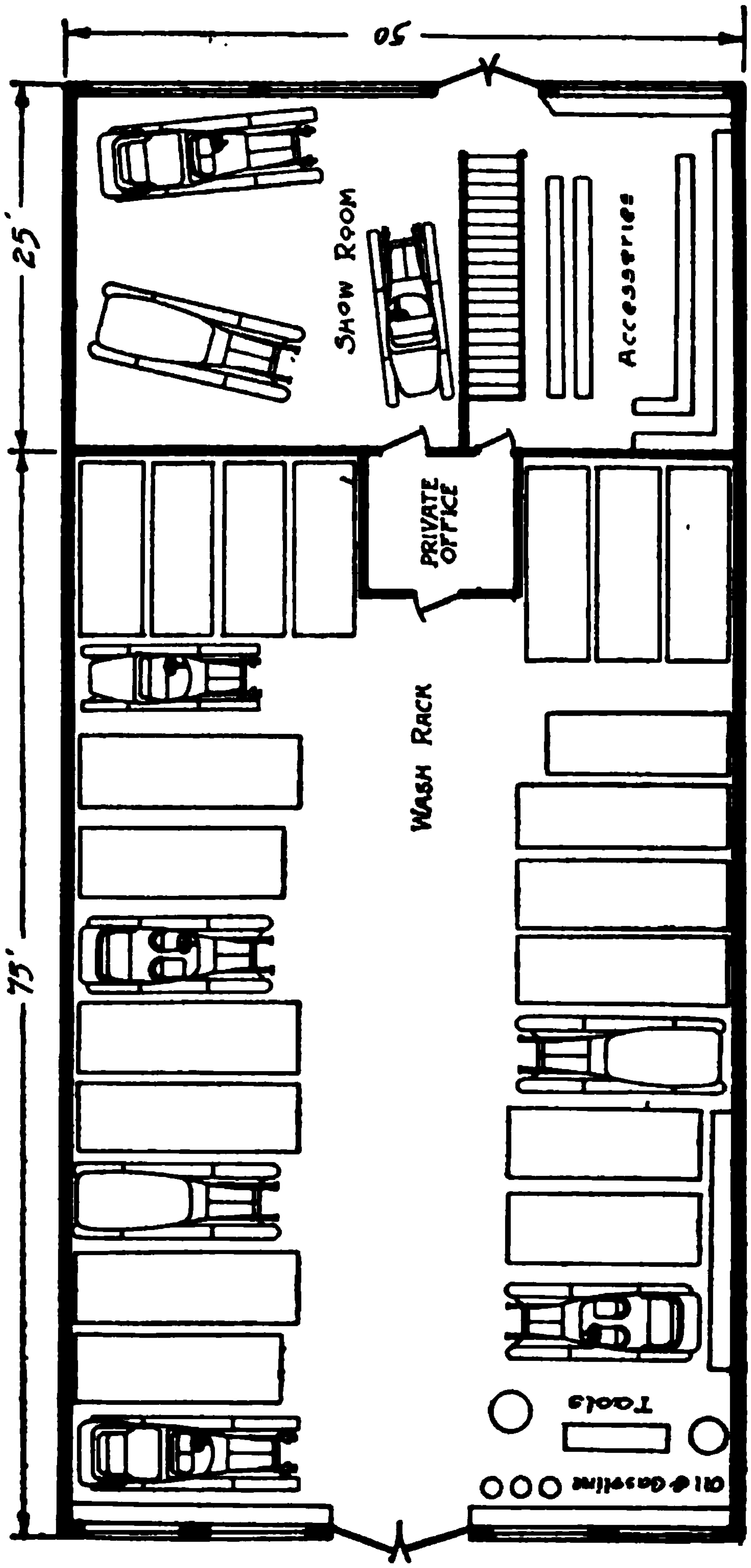



**Fig. 6. Rearrangement of Fig. 5 to Give More Car Storage Space**

**of the entrance, of the two salesrooms, office, stock room, and men's toilet. It is intended for the man or firm wishing to have considerable window display space at the front, and, for that reason, both the salesroom window at the right and the other window at the left**

are arranged for displays. The window at the right is for cars, while the one at the left is for small parts. A good idea of this plan is obtained from the front view of the establishment, Fig. 8. This

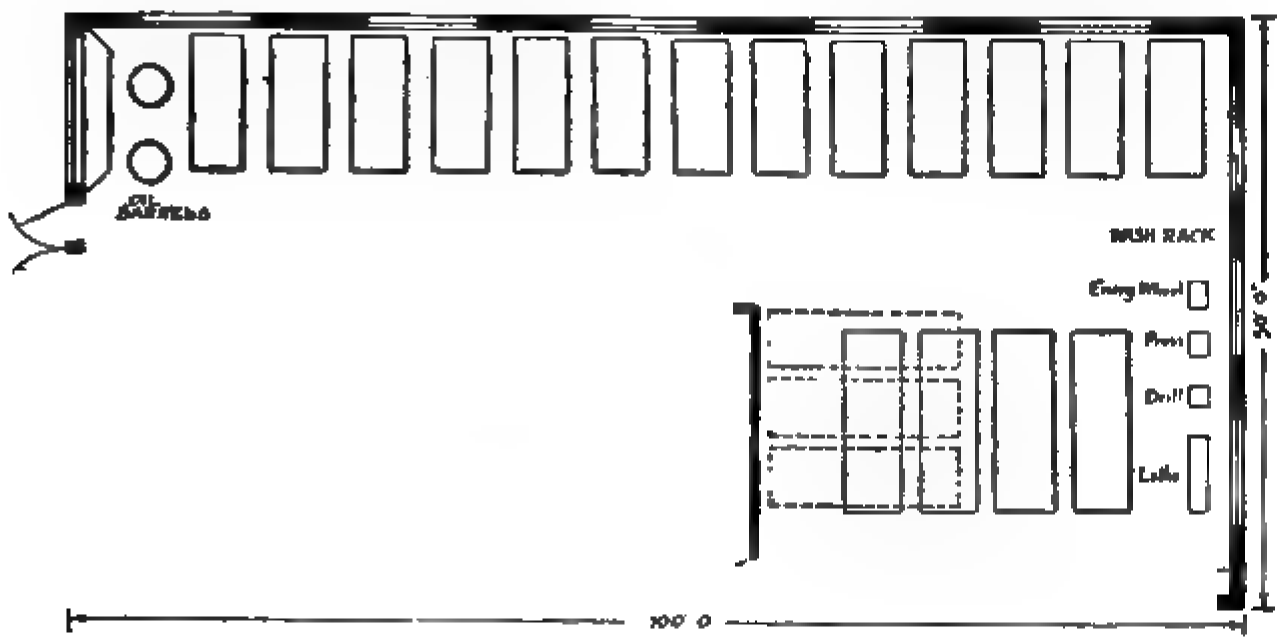



**Fig. 7. Different Arrangement of Small Garage with Show Rooms and Offices**
*Courtesy of "Motor World"*

plan is mentioned because it has a bearing on the floor space available for car storage, the display window for accessories and the oil-barrel arrangement just back of it taking up the space of one car.

**Fig. 8. General Appearance of Front of Garage Shown in Fig. 7 Plan**
*Courtesy of "Motor World"*

A modest repair outfit at the rear is composed of a work bench, lathe, drill, emery wheel, and press. The capacity, as shown, is for 17 cars, but by arranging the cars directly back of the accessory and parts stock room and parallel to the aisle, as shown in the dotted lines, one car can be added, making the total 18.

*Modification of Layout* 5. Considering the diversity of other things provided for, this layout seems excellent. For the man who might like this arrangement, yet who does not wish to give any space to car sales, the layout shown in Fig. 7 can be modified. The oil barrels can be removed and the accessory department moved to the extreme front, while the accessories and parts stock room can be eliminated. If the garage man sold only small accessories—the little things which could be handled at a simple counter or from ordinary shelves on the wall back of the counter—he would need little or no stock room, as such storage room as was needed for excess stock could be found under the counter, on the top shelves, or elsewhere. By this rearrangement, as can easily be figured, 8 or 9 cars may be added, making the total 25 to 26 cars, without changing the front or general good arrangement; in short, the layout shown in Fig. 7 provides for a car-agency arrangement, and also storage for 17 or 18 cars. The same layout without the agency space can be arranged for the storage of 25 or 26 cars.

In making his initial plans and the building layout, the garage man must balance his income from storage plus that from car sales against the increased income from storage alone, that is, in the two layouts just shown in Fig. 7 and its suggested change, he must figure out whether he will make more money from a 17- or 18-car garage and a sales agency, or from a 25- or 26-car garage and no sales agency. The accessory sales are about the same in the two cases, although possibly in the case of having a car agency, he might sell more accessories to the people who bought cars from him. This question, however, is problematical.

## MEDIUM SIZE GARAGE

**Typical Arrangements.** *Layout 6.* In the following, a garage is considered of medium size, which has a floor space of approximately 10,000 to 12,000 square feet. In a square form, this gives from 100 x 100 to 100 x 120 feet, and in a long narrow form, 60 x 200 feet, with various other forms in between these two. As a matter of fact, neither the exactly square form nor the unusually long and very narrow shape is an advantageous one. A floor plan of a Brooklyn, New York, public garage is shown in Fig. 9. This garage measures exactly 100 feet each way. It is on a corner, with an

entrance on each street. Moreover, the single central post appears to give a maximum of floor space. The supply room and the office are small, and apparently little space is wasted or taken up for things other than car storage. Yet, when we come to figure out the number of cars which this building will store—only 30, as can be figured from the plan, Fig. 9, and with little or no aisle room, so that cars would have to be moved every time one not in the first row was taken out—the truth of the statement that the square shape is not economical is proved. By inspecting this layout for an opportunity to improve upon it, we see that only two things can be rearranged to advantage. One is to reduce the number and size of the lockers. This size and arrangement may have been forced by local conditions, competition, or by some other reason, but even that arrangement of lockers is not as good nor as economical of space as if they were grouped in one corner.

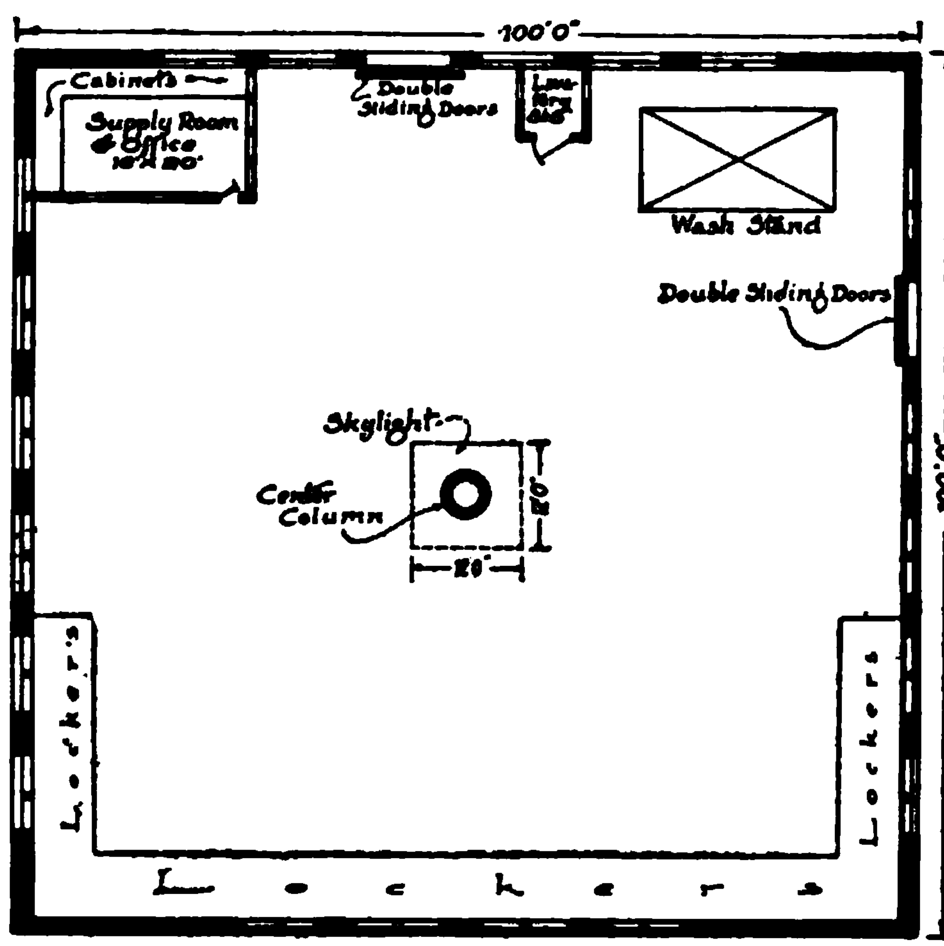


Fig. 9. Brooklyn Medium Size (100 x 100) Garage, Located on Corner

The washstand, however, seems to occupy the best corner of the building, yet there is a space on the Sea Gate Avenue front, between the office and the door, which is large enough for the washstand but which will hold only one car. By moving the washstand to this spot, the other corner would be available for cars. These spaces are shown by the dotted lines, which indicate that four cars could be put in the space now occupied by the washstand and this number, less the one lost in the other corner, would make a net gain of 3, bringing the total to 33 cars. If, now, it were possible to place the lavatory in a corner of the office space by slightly reducing its size, say from 8 x 8 to 6 x 7, two cars could be put in the space which it now occupies. So this square shape could store as many as 35 cars.

It compares unfavorably with the preceding layout, the rearranged Fig. 7, which was only 50 x 100 and was rearranged to

house 24 cars, while this 100 x 100 can hold but 35. If this shape were as efficient as the other, the doubled size should hold at least twice as many cars, or 48.

*Layout 7.* A New Jersey establishment, very long and narrow in shape, is shown in Fig. 10. This garage is built on a corner and extends through to a rear street, so that it has three street fronts. The third street front is utilized only for light, as the location of the repair shop at the end precludes having an entrance there. The dimensions show that this garage is not quite as large as the other, since it has but 8100 square feet of floor space. Moreover, it is so narrow that a row of cars cannot be put along each of the two walls to take advantage of the length. The best that can be done is 20 cars along the one all, with a maximum of 6 along the street wall, and even this number can be obtained only by placing them at an angle. The repair shop is sufficiently large so that it might easily hold 5 cars on which work was being done. This gives a maximum of 31, or if the repair shop be considered as separate from the storage, 25 only.

Fig. 10. Long and Narrow New Jersey Garage, Which Is Wasteful of Space

Two ways of improving layout 7 suggest themselves. One of these is to move the chauffeur's room, charging panels, and transformer inside the repair shop; by doing this, storage space for 2 more cars along the wall could be gained. The other method would be to move the repair shop up alongside of the office and the tire room. This can be done in two ways: It can be placed along the back wall, where a depth of 49 feet would give it about 60 per cent of its present space, replacing 7 cars. Then at the rear, in its former space,

providing the vulcanizers were moved with it, space for a total of 9 cars could be made. This would be a gain of 2 cars, which, with the previous gain of 2 by moving the chauffeur's room, gives a total of 30 storage cars. On the other hand, the repair shop would be so small that it could accommodate but three cars for repairs.

The way to improve this layout would be to place the office and tire room back alongside the repair room, allowing the repair room to occupy the full width of the building. In this rearrangement, the chauffeur's room, charging panels, and transformers would be taken care of also, so that while 16 feet would be taken off the length, the entire balance of the floor space would be available for storage of cars. This rearrangement would not take off anything at the rear, and the space added at the front corner would store 6 cars, while one more could be set at an angle against the outside wall. This plan, then, would bring the total capacity of this long narrow garage up to 33 cars. The only way in which the layout could be further improved would be by the removal of one of the doors on Railroad Avenue; by doing this, 2 more cars could be set at an angle along that wall, making a total of 35. When cars are set at an angle like this, however, the projecting corner of each car makes a bad point to pass, as this corner is a fender, which is a rather weak unsupported part. This arrangement, too, cuts down the available aisle to a space scarcely sufficient for cars to pass through, certainly not enough for them to pass through at speed.

*Layout 8.* Both the above arrangements provide for car storage and small accessories only, one having a repair shop, with battery-charging and tire-repair facilities, but neither having car sales space. A layout with slightly more floor space is shown in Fig. 11. This layout is an irregular space having a tapering corner which renders it doubly interesting, and space is provided for painting and trimming, also for a small car salesroom, and for an additional store that could be rented. The car space will store an even 40 cars, while the repair shop provides space for 6 more, and the paint shop and the trim room can accommodate 2 cars each, thus making room for a total of 50 cars in the establishment.

The building is on a corner and has entrances on three sides. If the prospective garage man has a layout like this, and if it were desirable to make it yield more revenue by adding storage space,

the elimination of the store and the small office corner would allow storage for about 8 more cars in that space. In figuring this space, however, the net additional revenue from 8 cars would have to be balanced against the net revenue from the rental of the store. In this layout, where the offices are at the front and the paint and trim shops are at the rear, the cars enter from the street at the right, while the other cars can enter either at the front or at the rear through the repair shop. Consequently, the space at the rear end of the

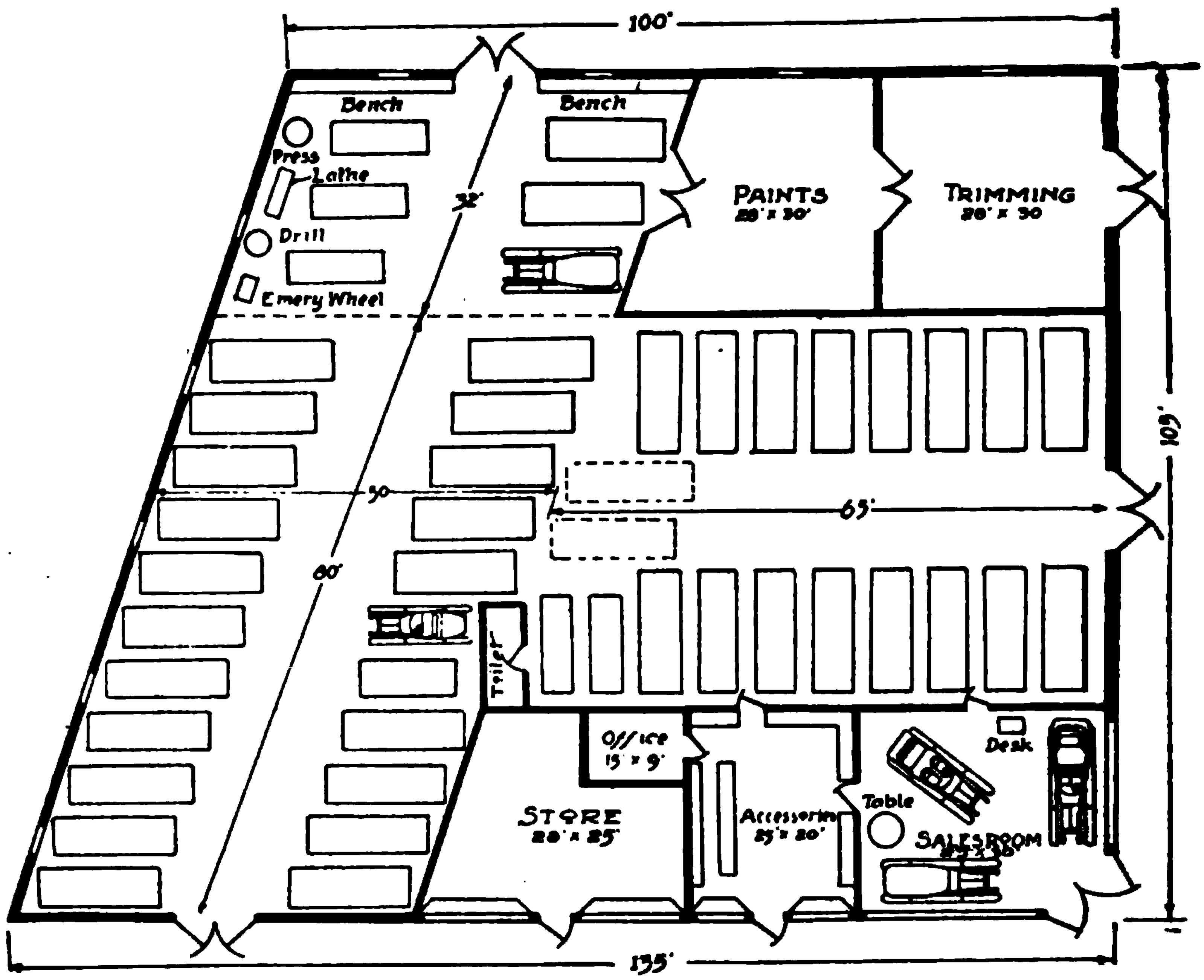



Fig. 11. Combined Garage, Salesroom, Paint, Trim, and Repair Shop on Irregular Corner
*Courtesy of "Motor World"*

right portion of the building could be used for two more cars, as the dotted lines show. These two changes would bring the capacity up to 50 storage cars, with 10 more cars in the three shops, so there would be a source of revenue from a total of 60 cars.

As the tapering corner is the part that gives the trouble, layout 8 might be improved by using this irregular portion for the three shops. If a partition were run from the back to the front, between the door and the window in the far corner and parallel with the right side until it met the present office lines, it would leave a car

storage space 85 x 60 feet, with square corners and three entrances. It would also give all the office space of this layout and allow the shops more floor space than they have, that is, over 3400 feet as compared with over 3000 feet. This layout, shown in Fig. 12, by narrowing down the present aisle from the street at the right and putting in another double row toward the back would permit storing 47 cars. In addition, two more cars could be put in the corner where the two aisles meet, thus giving storage for 49 cars as compared

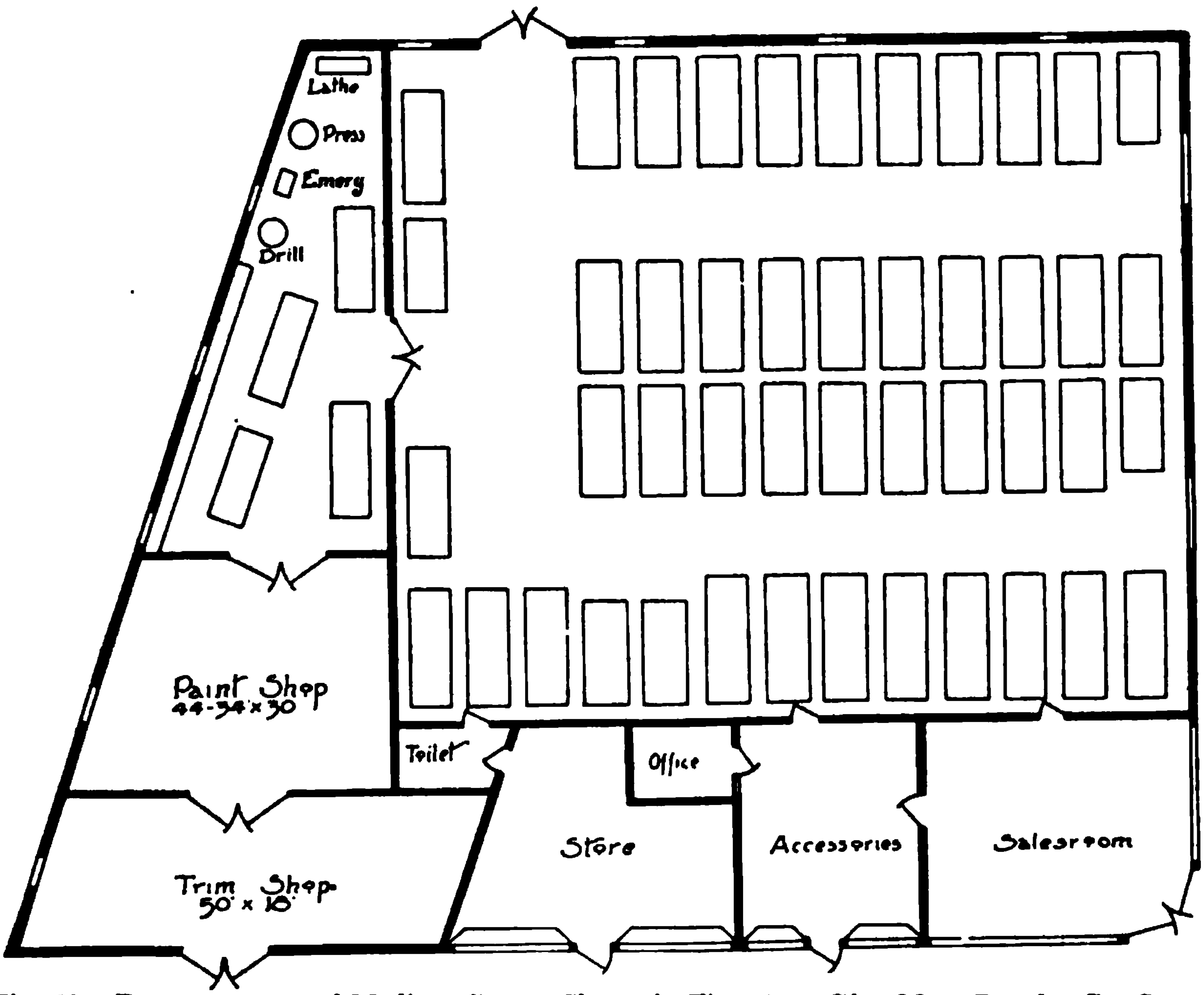



Fig. 12. Rearrangement of Medium Garage Shown in Fig. 11, to Give More Regular Car Space

with the present 40, and yet retaining all the present advantages. This might seem a small amount for so much trouble, but it can be figured as follows; If one car pays a minimum of $20 a month, which is $240 a year, 9 cars would add $2160 a year or, in round figures, $2000. At the same time, all three repair shops have more space than previously, and the garage space is cut down to a rectangular shape, with four square corners, making it easy to arrange, use, and keep clean. This rearrangement also makes the garage portion more accessible for cars, despite the fact that the front street entrance is eliminated in so far as the garage portion is concerned.

## LARGE SIZE GARAGE

**General Characteristics.** A garage is considered large which has in excess of 20,000 feet floor space, that is, while the small garage would have about 5000 feet, and the medium size garage somewhere near 10,000 feet, the larger form would be about twice the size of the medium, or four times the size of the small garage. As a general thing, there are few garages of this size, which would work out at somewhere between 60 x 340 for the longest and narrowest shape, and 150 x 150 for the square, that is, when a garage has sufficient business to warrant this much floor space, it is in a section where the land is too valuable to be used in the form of a one-story building, for which reason most of the large garages occupy two stories, two stories and basement, three stories, or even more. This immediately brings in a point not previously touched upon, namely, the method of handling the cars on other floors than the ground floor.

**Elevators vs. Ramps.** In garages of more than one story, the cars are handled in one of two ways, by means of elevators or by inclines called ramps. Ramps have come into use in the last few years, and present the following advantages: They are usable at will, at any time of the day or night; the attendant and the machinery to run the elevator are eliminated, as is also the danger from the open pit. The ramp minimizes the fire hazard, which the elevator shaft always increases by providing a natural chimney, while ramps are never continuous from basement to top floor, and are made of concrete. On the other hand, they take up more space on all floors than elevators. Where the layout of the building allows it, however, they are considered a better investment. Certainly, from a service viewpoint, ramps can and do render much quicker and more efficient service than any number of elevators. They are said to cost less, for the increase in the building cost is more than offset by the saving in the cost of the elevator and its machinery.

In the large garages to be shown and described, some have elevators and others have ramps, and although no direct means of comparison is afforded, an analysis can be made in every case, and the question of which method would have been better can be settled.

**Typical Arrangements.** *Layout 9.* Fig. 13 shows a one-story garage of the amount of floor space which entitles it to be called large. It is an old remodeled building with a width sufficient to

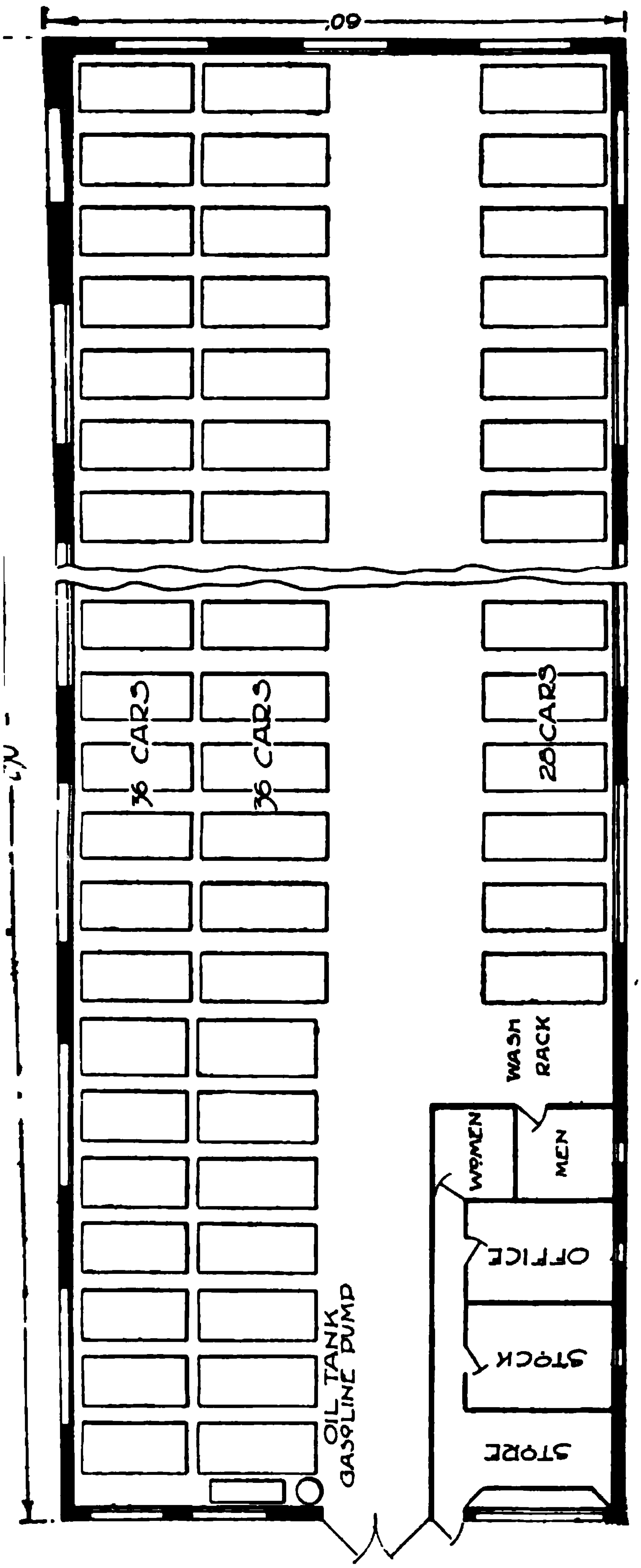



Fig. 13. Very Long and Narrow Building Made into 100-Car Garage with Very Regular Layout
*Courtesy of "Motor World"*

allow the arrangement *B*, shown in Fig. 1. With this arrangement the building has room for 100 cars. There is provision for a small store, a stock room, office, toilets for men and women, wash rack, also fuel and oil pumps. The latter are placed at the street front, just inside the door. The building, although as long as the average block is deep, does not run through to another street, so there is no back entrance. This plan makes it possible for some cars to be placed at the back end of the aisle against the rear wall and as far forward as seems advisable, as indicated by the dotted lines. Despite the number of windows on all four sides, it is advisable to have several skylights in a building of this size and shape. In an old building altered for garage use, the better way is to cut the skylights through the roof.

*Use of Basement.* This layout, beyond its unusual length, shows few, if any, features. It has, however, everything on one

floor. When it comes to building several stories, the question arises as to whether it is cheaper to excavate a full basement and use that, or to merely go down far enough for foundations and build one story higher to offset the lack of a basement. In a specific case where three floors are needed, they can be obtained by the use of a basement and two stories, or three stories above ground and no basement.

The question of which construction is better must be settled by local conditions. If the general increase appears to promise a need for more space in a few years, the basement and two-story building would provide the three floors for the present need, and the walls could be made heavy enough for the addition of one or more floors above, later. On the other hand, the three floors might represent the limit of future expansion, that is, as far as the garage man could see ahead, while excavation was high priced, or the site contained rock or something of that sort. At any rate, it is a question to be settled in advance, for the basement cannot be put in after the building is erected.

Steady boarders do not like the basement unless it is unusually well lighted and kept very clean. But this is not a great disadvantage, as there are many things about a garage that patrons do not like. If a choice is offered between a basement with a ramp and a third story, the patron will take the basement every time. From the viewpoint of some garage men, the basement has the advantage of lacking in natural light, and there is a disinclination on the part of patrons whose cars are located there to work on them, consequently the garage gets more work than it would if all cars were on or above the ground level where the floors are well lighted and the owner is given to doing much of his own work.

*Layout 10.* A three-floor garage with two elevators is shown in Fig. 14. This might be either a basement and two-story building or a three-story building. The layout includes a repair shop and a paint shop, located at the rear of the top floor for the best light and occupying the full width of the building. On the ground floor is a salesroom, accessory sales space, stock room, office, a private room, and toilets for men and women. In the car-storage space are two wash racks, located directly in front of the two side entrances. The lack of wash racks above the ground floor would appear to be a big disadvantage here, for the 54 cars on the second and the 33 cars on

the top floor would have to be brought down one at a time, washed, and then taken up again, or else not washed at all.

Since a paint shop needs a form of wash bench, it would seem as though one should have been laid out on the top floor in connection with the paint shop and another on the second floor, to obviate this drawback. On the other hand, a garage of this type will often rent most of its entire top floor, totaling, in this case, space for 33 cars, for dead storage, the balance being occupied by cars to be repaired, for which there is not room in the repair shop. In this case, no washing

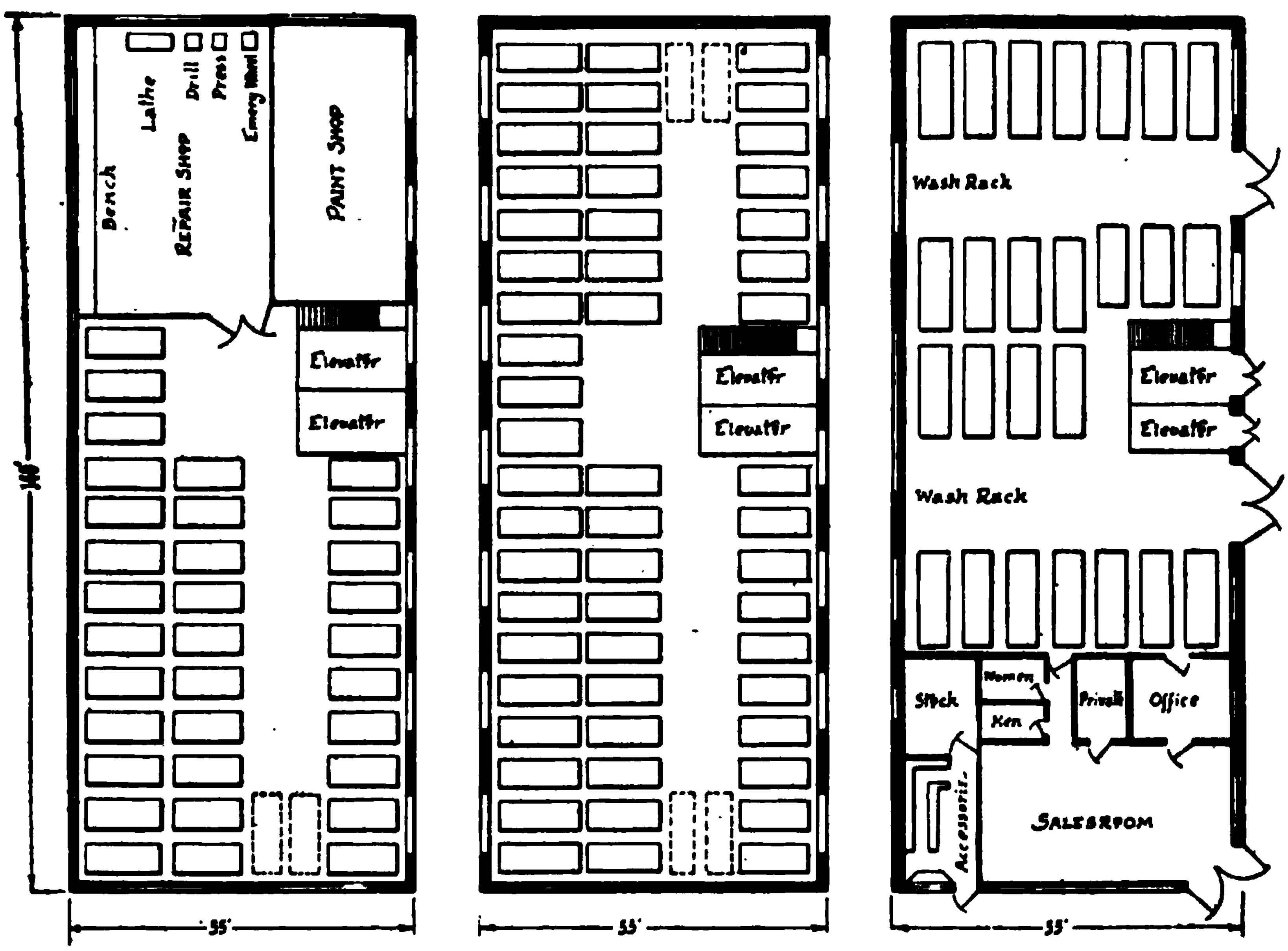



Fig. 14. Arrangement of Three-Story Garage, in Which Two Elevators, Side by Side, Are Used

or other attention need be given the cars; so, in the usual garage, the need of light and heat would be eliminated. It is an excellent layout, and could not be improved upon for quantity or economy of space, unless the ends of the aisles at the front and back of the building were used. As the dotted lines show, this would add room for four cars on the second floor and two on the top.

*Improvements of Layout 10.* The elevator arrangement in this building might be criticised on the ground that the two elevators are so close together and so located in the middle of the building as to be no better than one, except for frequency of service. As they are

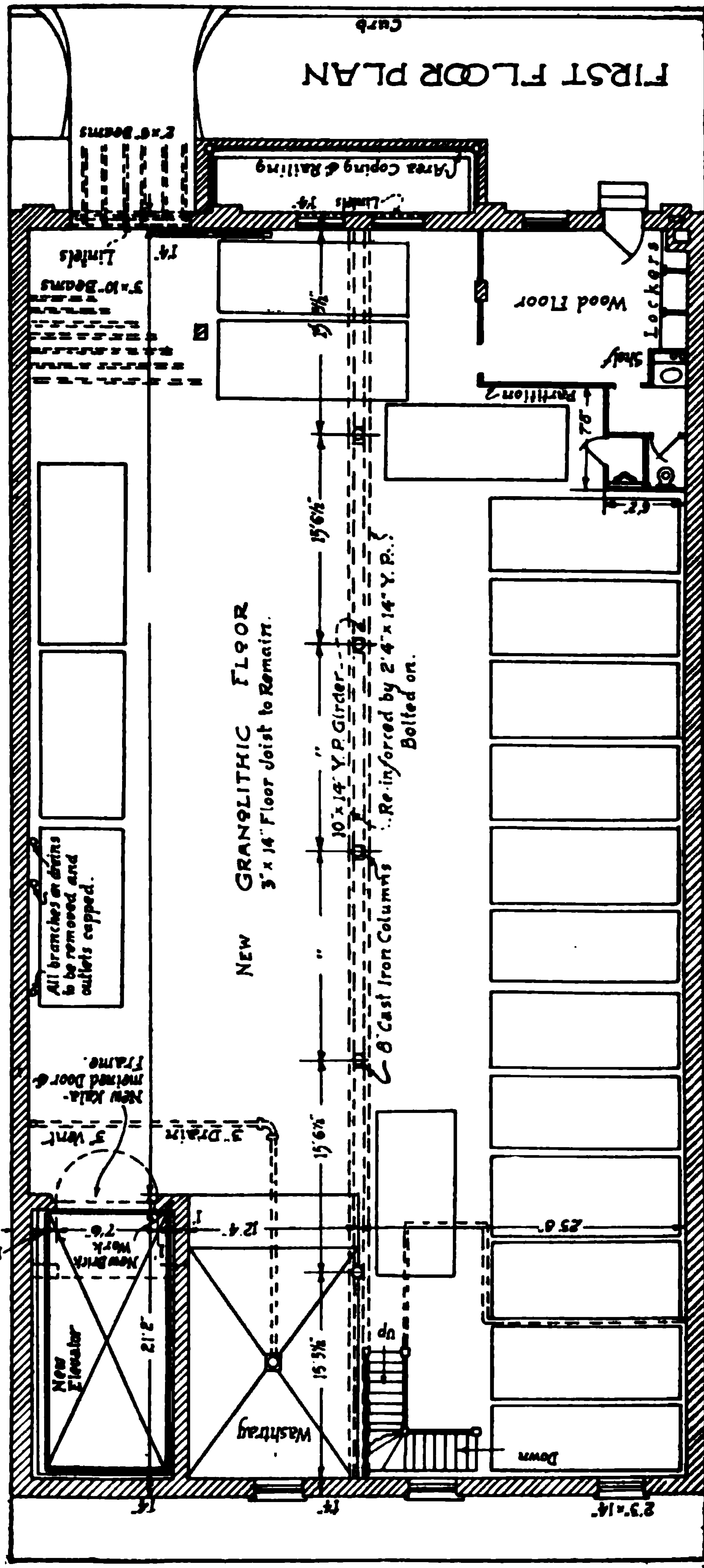



Fig. 15. Ground Floor Layout of Narrow City Garage with Entrance at One Side

placed, they take out the space of three cars on every floor. If they had been placed back in the corner at the rear, only two cars each would have been displaced on the ground and second floors, but the paint shop arrangement would have been upset, and there would still have been the objection of two elevators side by side being little better than one. If the elevator nearest the front were left where it is, and the other one moved back to the rear corner, the two cars displaced on the ground floor would have been offset by the three which could be added at the present position, thus gaining one. On the second floor, the two cars displaced would just equal the two which could be added, while on the top floor two cars would be added, so that the net result would be 3 car spaces gained. In addition, the paint, repair shops, and the second floor would get better elevator service.

*Layout 11.* A typical city garage, built on a very narrow lot, so narrow that the garage floor space is not economical, is shown in Fig. 15. This is the first-floor plan, as the basement is not used for cars, although the three upper floors are. The arrangement shown, with the office, clothes closets, and toilet in one corner at the front, the entrance on one side, with the elevator at the rear on the same side, the wash rack alongside the elevator, and the stairs close to the wash rack, all cut into the space so that but 19 cars can be housed. If the building were a few feet wider and had the entrance in the middle, the cars could be lined up along the two walls, in which case the single floor capacity would be in excess of 32 cars. On the upper floors this is actually done, as a large percentage of the vehicles are taxicabs, the owner of this garage being interested in a taxicab company. These taxicabs are small, being shorter than regular touring cars, and therefore need less space for standing room and for maneuvering. As a result, the second floor houses 30 cars, the third floor 30, and the top floor about 10, the balance of this floor being given up to the repair, paint, and trim shops, and to cars waiting to be put in shape. There is a wash rack on both the second and the third floors, immediately above the one shown on the ground floor. The whole makes a convenient arrangement, considering what the building is and the impossibility of lengthening or widening it, or of making any other material change. Fig. 16 shows a photograph taken on the ground floor, and Fig. 17 shows one of the upper floors. These pictures show no crowding, as they were taken during

Fig. 17. Second Floor View of the Same Garage, Showing Lighting and Washing Provisions

which is used. The connection from ground floor to basement is by a ramp along one wall, but so placed as to have direct access to the street. There is provision in one corner for a small car salesroom, an accessory salesroom, stock room, private office, and a general room, also an aisle to the shop, off of which are the toilets, as well as a fair size store for renting. On this floor are also two wash racks

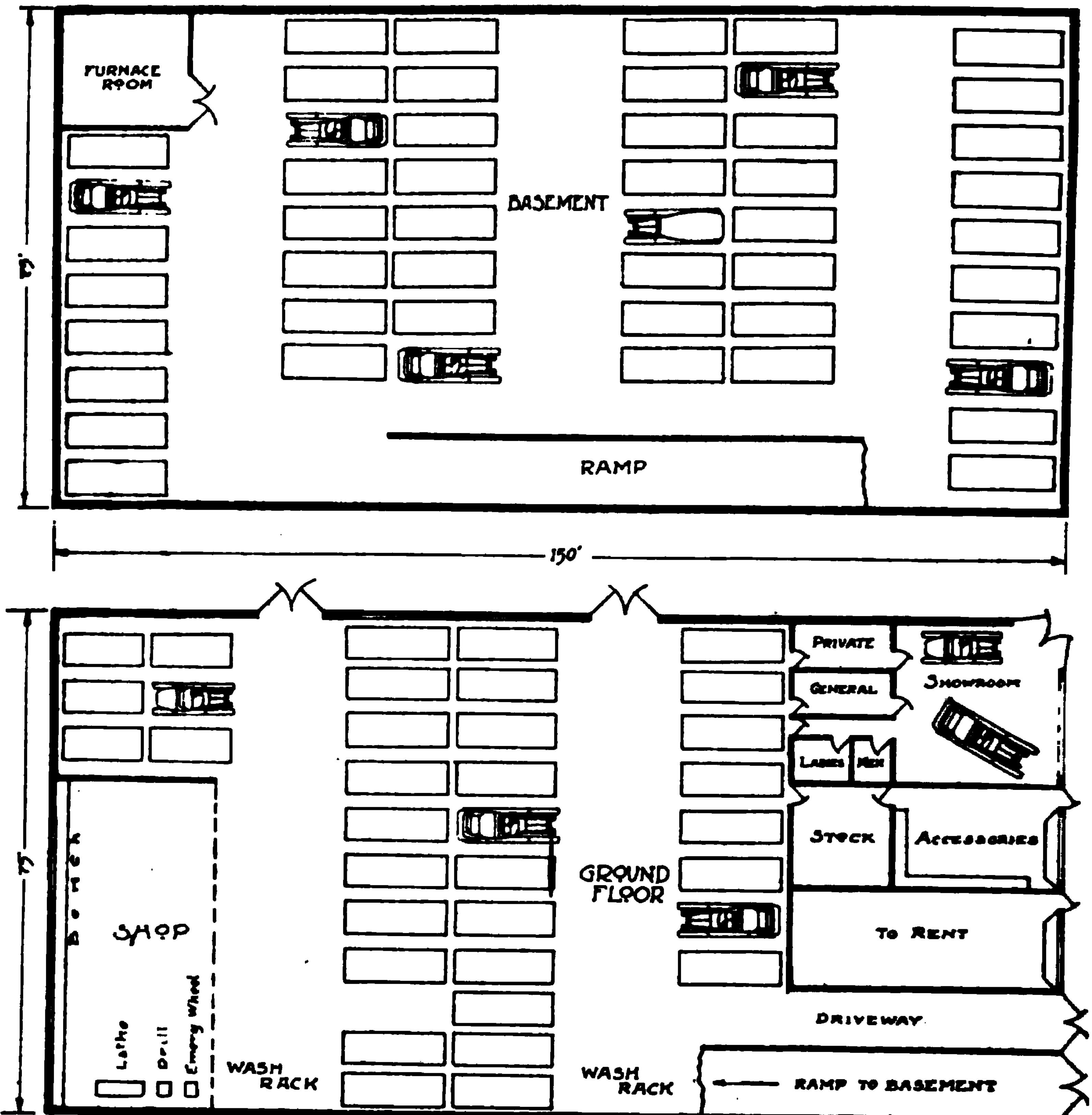



**Fig. 18. Basement and Ground Floor of a Large Garage, Using Ramps**
*Courtesy of "Motor World"*

and a fair size repair shop. The basement has no provision except for cars, and a furnace room in one corner, which houses the heater and the coal. It accommodates 50 cars, despite the ramp and many aisles. The capacity could be increased to 60 cars, by putting them in the ends of the aisles against the walls and under the ramp.

On the ground floor are three entrances, which give easy and quick access to the cars. The arrangement is good, compact, and

efficient, the ends of all aisles forming the wash racks. The capacity might be increased by taking out the store for renting and utilizing the space for cars. By making this change, 6 more cars could be accommodated. The present total is 35, and this would bring it up to 41. In considering this change, the revenue from 6 cars the year round would have to be balanced against the annual rent of a store of this size. The whole building now houses 85 cars, but with the suggestions made, it could handle 100, as it has 22,500 square feet of floor space. This gives an average of 265 square feet per car for the original layout and 225 for the modification. As a car occupies but 15 x 7 feet or 105 square feet, it can be seen that this garage, which has a good average layout, is about 40 per cent efficient, and could be made 47 per cent. It is an unusually good layout which works out at 50 per cent, everything considered.

## VERY LARGE GARAGE

When a garage can or does house in excess of 100 cars, or when its floor space is 30,000 square feet or more, it is not an exaggeration to call it a very large one. The very large garage is interesting beyond the other forms just described because its equipment is usually more complete, it possesses more facilities for doing work, its arrangement is generally studied out more carefully because of the enormous investment, and because of the number of cars which must be over-handled.

**Typical Arrangements.** *Layout 13.* An unusually large garage is shown in plan view in Fig. 19. This is unusual for the reason that it houses only 100 cars and a few odd dead-storage vehicles when its width and length would allow the handling of almost twice that number with ease. It is one story high, without a basement, and has a chauffeur's room, a toilet, an office, a storeroom, and a wash rack, all housed in an L near the center of one side. Aside from vacuum-cleaning machinery, the balance of the entire floor, which runs clear through a city block, is available for cars. This space is 88 feet wide and 275 feet long, sufficiently wide for an arrangement like *C*, Fig. 1, with an additional width of 8 feet in the center aisle. This arrangement provides for 4 cars per 7 feet of length. The garage shown is 275 feet long, so there could be 39 such strips. Even if 2 cars were omitted to make room for the vacuum machinery, and 4 more in

front of the office and wash rack, there would still be space for 150 cars with a central aisle of unusual width. The garage actually has 100 and will take no more.

*Use of Vacuum Arrangement.* The vacuum machinery is an unusual feature. It removes all dirt and dust from all cars. The machinery is connected to each car space by means of a 2½-inch pipe, while a removable hose with a nozzle is carried around by the workman. Another unusual feature is that the machine shop, which is large and unusually well equipped, is located two blocks away. In addition to its broad central aisle, approximating 58 feet with but two rows of cars along the walls, two very large central skylights

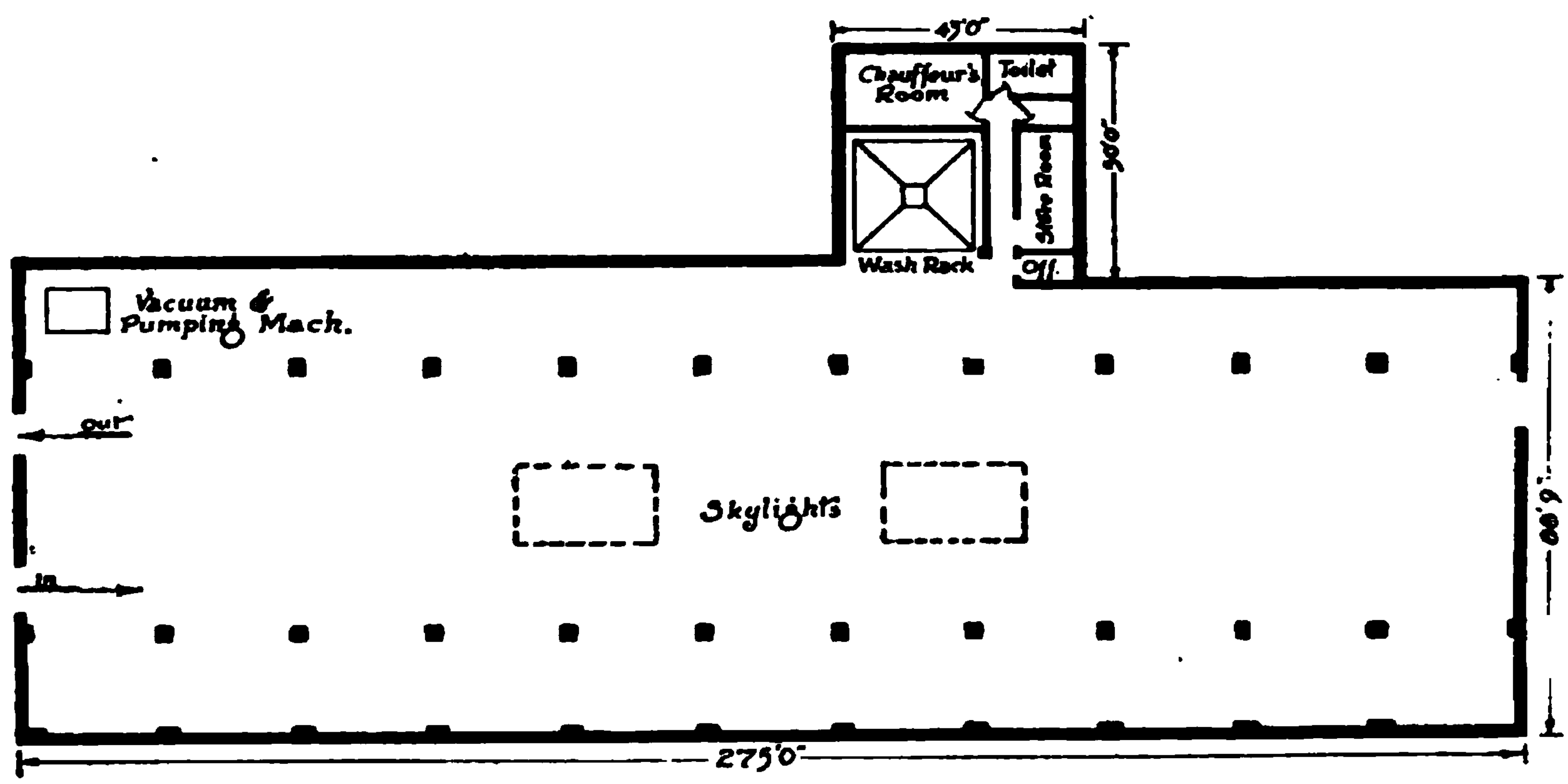



Fig. 19. Very Large Western Garage Which Runs through the Block

make it very light and airy. Another feature is that each car space has a steel locker 40 inches one way, so that the largest tires in use can be stored there with perfect safety. The arrangement of the entrances is well worked out. On the street at the right there is but one entrance, this being used for both entrance and exit, but on the other street, where there are two, one is used for entrance only, and other for exit only.

*Layout 14.* Another very large garage is shown in Fig. 20. This garage has a shape not unlike the one shown in Figs. 11 and 12, and the size is not radically different, being 100 feet wide by from 100 to 154 feet long, an average length of 127 feet. It differs from the other in that perhaps 50 per cent of the ground floor space is given over to salesrooms, offices, elevators, and apparatus, and also in having four floors and a roof; the roof is a special feature to be

spoken of later. This garage was built for and is run in connection with the sales agency for one of the largest cars, hence the amount of space given over to the salesrooms at the front of the building. While the single elevator might be thought inadequate for a building of this size and height, in combination with the turntables provided—

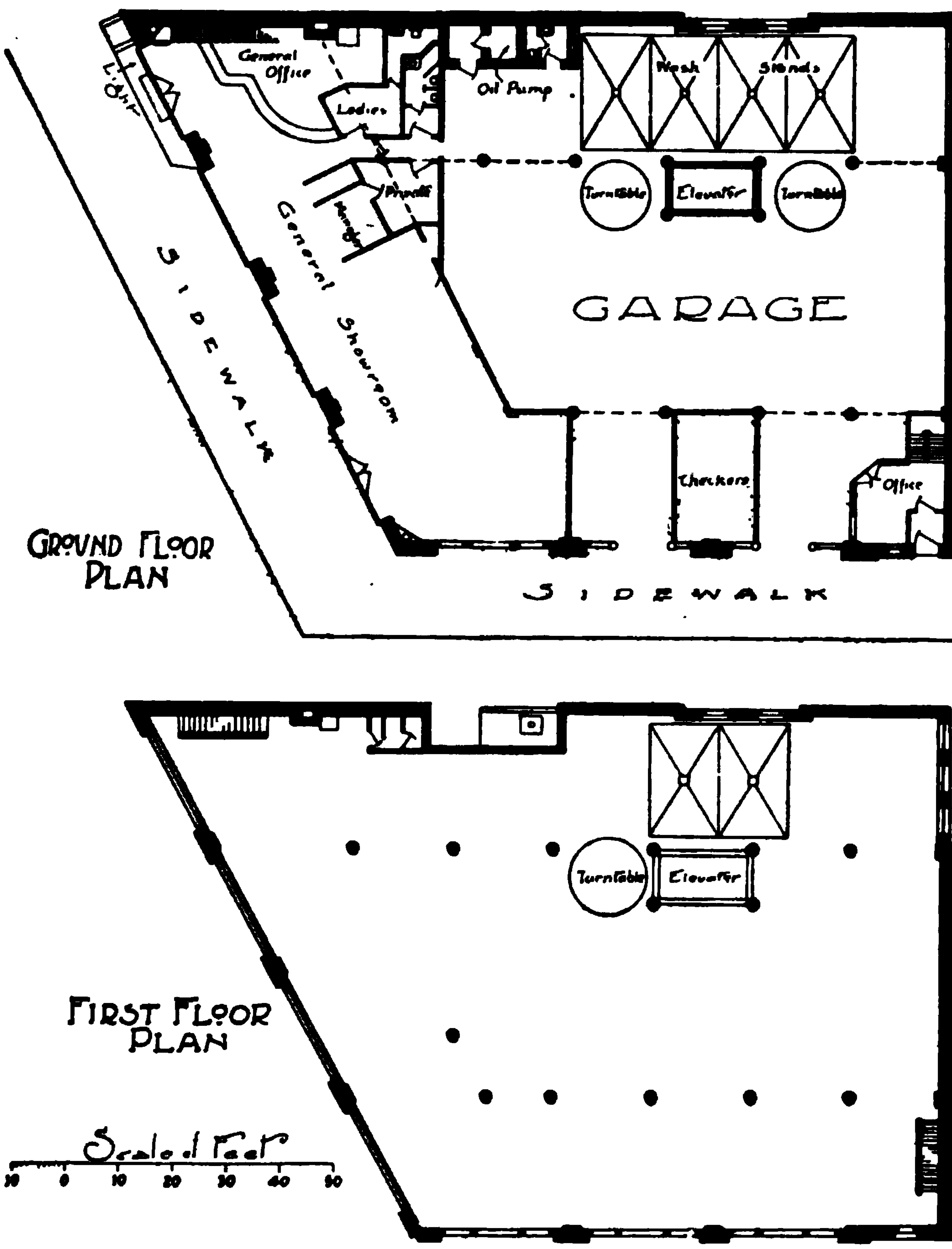



Fig. 20. Very Large New York City Garage with Many Unusual Features

two on the ground floor and one on every other floor except the roof—it is quite sufficient, and there is seldom, if ever, any waiting.

The car capacity is 20 on the ground floor; 60 on the second floor; 75 to 80 on the third, which is utilized for dead storage; and from 40 cars upwards on the fourth, which has a large and very

well equipped repair shop; and 25 cars on the roof. The latter is a distinct feature never seen elsewhere. The building has a high ornamental coping rising more than 10 feet above the roof, which is covered with tile. Inside of this coping, around the two sides of the obtuse angle, that is, the south and west sides, a light roof has been carried in for 25 or 30 feet, making a protected space of that width along those two sides. As the elevator runs up high enough to serve the roof as well as the lower floors, cars can be placed in this space and be as well protected as on any lower floor, except against a driving rain or snow from the north or east, accompained by a very high wind. Even then it is doubtful if the car would get wet. This space, in summer months, is as good as space anywhere else in the building. The length of the roof along these two sides is such that the cars can be placed end to end along it and still leave over 10 feet of working space under the light roof. This gives a capacity, in round figures, of 150 cars on live and 75 to 80 on dead storage, or 225 to 230 cars total which the garage handles. About 50 men, exclusive of sales and office employees, are needed to handle this number properly.

Prices for Service. The prices, which are those of the trade association, are about as follows:

STANDARD GARAGE CHARGES IN NEW YORK CITY

| | |
|---|---|
| Runabouts below 20 h.p. | $20.00 |
| Touring cars from 20 to 40 h.p. | 30.00 to $35.00 |
| Touring cars over 40 h.p. | 40.00 |
| Roadsters over 40 h.p. | 30.00 to 35.00 |
| Landaulets, any power | 30.00 to 35.00 |
| Limousines, any power | 35.00 to 45.00 |
| Transient storage, per night, no cleaning | 1.00 |
| Repair work, per hour | .75 |
| Dead storage | 10.00 and up |

Striking a rough average of the 150 cars on live storage at $30 would give a monthly revenue of $4500, and the dead storage on the 80 cars at $12 would bring in $960 a month, a total of $5460 a month, or $65,520 a year. This estimate is exclusive of repair work, spare parts, accessories, oil, gasoline, grease, waste, etc., all of which would probably bring the yearly income up to $75,000.

*Layout 15.* Another very large garage, interesting by reason of having ramps up to the third floor, is shown in Fig. 21. Not that

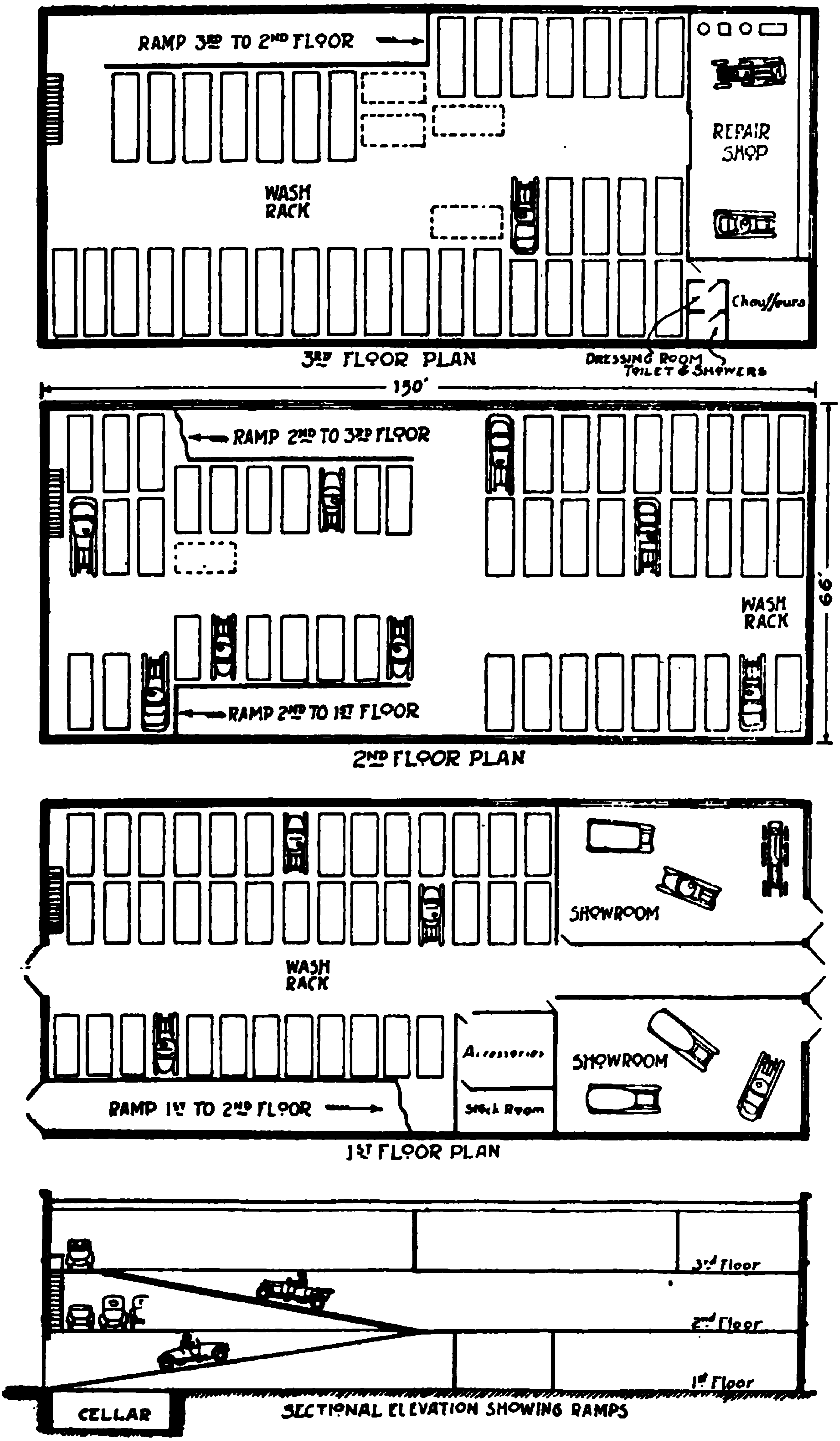



**Fig. 21. Floor Plans and Sectional Elevation of Very Large Three-Story Garage Using Ramps**
*Courtesy of "Motor World"*

ramps cannot be used as high up as desired (6, 8, or even 10 stories), but it is unusual. When a high building is considered, the elevator is usually thought best, while ramps have the preference in a low one. This garage, with its three floors, has almost exactly 30,000 feet of floor space, housing 127 cars and giving an average of slightly over 236 square feet per car, as against the 105 considered necessary. This garage has an efficiency of 44.5 per cent.

The ground floor has two unusually large show rooms at the front, on either side of an entrance, with an accessory salesroom and stock of parts back of one of them. At the rear are two more entrances, one central, the other to the ramp. The wash rack is in the center of the aisle, midway of its length, and thus handy from both ends. The second floor is very simple, with the ramp coming up close to one side wall, crossing the building and going on up alongside of the other wall. This influences the layout of the cars, which is square and very simple, with a wash rack at the end of the large longitudinal aisle. The third floor has the ramp coming up at one side near the end, while the repair shop is across the rear end. This combination calls for a broad center-aisle space and considerable other waste room. Even with this waste, the ground floor has spaces for 40 cars, the second for 50, and the third for 37 cars, outside of those in the repair shop. One car could be added on the second floor, and two or three on the third, without disturbing anything, as shown by the dotted lines. The sketch at the bottom shows how the ramps proceed from floor to floor. The big problem in laying these out is to balance the desire to save as much space as possible against the keeping of the slope within a reasonable figure. Of course, cars coming in under their own power can negotiate slopes up which it would be very difficult to push a car by hand.

## FINANCES AND BUILDING COSTS

**Income and Expense Estimates.** As something has been said about costs and also about revenue, it will be well to take up the subject of financing. In this connection, the sets of figures in Tables I and II are of pertinent interest. A group of men planning a large garage in New York City brought the estimate of costs, as given in Table I, to the writer for comment. In this estimate it seemed

that everything was figured and figured properly, yet there was no profit. The amount left for net income, $6900, was but 2¾ per cent on the total investment, and was not considered an adequate return.

*Analysis of Actual Estimate.* The writer was asked to go over the figures and see what was the matter with them. The biggest item was that of the building itself, and it was discovered that this had been figured at 18 cents per cubic foot, while good standard practice showed but 13 cents necessary in garage construction, and very serviceable garages had been built and were in satisfactory operation which cost but 12 cents per foot. As the idea here was to show an opportunity for large profit, the lower cost per foot was used as a basis for a revised estimate. This changed the building cost, the interest on the building while being built, the cost of obtaining a building loan on it, and, in the operating expense, lowered the annual interest charges.

On the other hand, no allowance had been made for equipment, elevators being included in the building cost, and other equipment was considered as "not costing much". In the matter of the number of machines, the spaces had not been well planned, and a rearrangement showed how 290 machines could be housed instead of 165. The district selected being an excellent one, where there were many cars and not many garages, also where the opportunity for motor trucks was beginning to show up very large, the vacant space was cut down from 20 per cent to 15 per cent. The revenue per car was refigured on the basis of actual gasoline, oil, and other supplies which an average city car would have to have, and the profit figured from this. It substituted a more exact method for a lump sum process.

*Analysis of Revised Estimate.* Table II shows the revised figures and indicates how the final profit of over 30 per cent was arrived at, this being over and above the 6 per cent interest on the money invested. In looking these figures over in the light of present conditions, it would seem as though fewer elevator men would be needed, but this would be offset by the fact that the office force seems inadequate for a building of this size and for the handling of such a large number of cars—almost 250—with the attendant number of book accounts.

## TABLE I

### Five-Story and Basement Garage

FIRST ESTIMATE OF COST

| | | |
|---|---|---|
| Ground | $60,000 | |
| Building (1,000,000 cu. ft. at 18 cts.) | 180,000 | |
| Architect | 2,000 | |
| Interest on ground during construction | 1,600 | |
| Interest on building during construction | 2,400 | |
| Taxes and insurance during construction | 1,000 | |
| Cost of obtaining loan | 5,000 | |
| Incidental expenses | 3,000 | |
| Total cost | | $255,000 |

FIRST ESTIMATE OF INCOME

| | | | |
|---|---|---|---|
| 5 Stories, 30 machines each at $30 average | $54,000 | | |
| Basement, 15 machines at $30 average | 5,400 | | |
| Gasoline, oils, etc., profit per month on each machine, $5 | 9,900 | | |
| | | $69,300 | |
| Running 80% full (deduct ⅕) | | 13,860 | |
| Total income | | | $55,440 |

FIRST ESTIMATE OF EXPENSES

| | | | |
|---|---|---|---|
| Interest at 6% on $255,000 | $15,300 | | |
| Annual taxes and insurance | 4,500 | | |
| Electric current for elevators, etc | 3,600 | | |
| Monthly supplies and sundry expenses | 1,800 | | |
| 1 Day superintendent at $150 per month | 1,800 | | |
| 1 Night superintendent at $100 per month | 1,200 | | |
| 1 Bookkeeper and stenographer at $75 per month | 900 | | |
| 8 Elevator men at $40 per month | 3,840 | | |
| 10 Floor men at $70 per month | 8,400 | | |
| 10 Washers at $60 per month | 7,200 | | |
| Total expenses | | $48,540 | |
| Estimated Net Income | | | $6,900 |

In submitting this second estimate, the writer made the point that the territory in which it was proposed to build this garage was a rich field for an electric garage, so that by investing an additional $6000 for switchboard, wiring, and plugs, and adding an electrician at $100 a month to the payroll, at least one-third of the capacity

## TABLE II

### Five-Story and Basement Garage

REVISED ESTIMATE OF COST

| | | |
|---|---|---|
| Ground | $60,000 | |
| Building (1,000,000 cu. ft. at 12 cts.) | 120,000 | |
| Equipment | 12,000 | |
| Architect | 2,000 | |
| Interest on ground during construction | 1,600 | |
| Interest on building during construction | 2,000 | |
| Taxes and insurance | 1,000 | |
| Cost of loan | 4,000 | |
| Incidental expenses | 3,000 | |
| Total cost | | $205,600 |

REVISED ESTIMATE OF INCOME

| | | | |
|---|---|---|---|
| 55 Cars a floor, 5 floors, at $30 a month per car | $99,000 | | |
| 15 cars in basement at $30 per car | 5,400 | | |
| Sale of gasoline on basis of 8 gallons a car per day, 3 cents profit on a gallon | 17,000 | | |
| Sale of oil, grease, and supplies at an average profit of 5 cents a car per day | 3,500 | | |
| Other revenue from rental of lockers, repair parts, charging, ignition, vehicle batteries, etc. | 2,000 | | |
| Total income | | $126,900 | |
| Deduct 15 per cent for space not filled | | 19,035 | |
| Total yearly revenue | | | $107,865 |

REVISED ESTIMATE OF EXPENSES

| | | |
|---|---|---|
| Interest at 6 per cent on $205,600 | $12,336 | |
| Annual taxes and insurance | 4,500 | |
| Electric current for elevators and for charging | 3,000 | |
| Monthly supplies and expenses | 1,800 | |
| 1 Day superintendent at $110 per month | 1,320 | |
| 1 Night superintendent at $110 per month | 1,320 | |
| 1 Bookkeeper and stenograper at $75 per month | 900 | |
| 6 Elevator men at $40 per month | 2,880 | |
| 10 Floor men at $70 per month | 8,400 | |
| 10 Washers at $60 per month | 7,200 | |
| Total expenses | | $43,656 |

SUMMARY

| | | |
|---|---|---|
| Yearly income, as above | $107,865 | |
| Yearly expenses, as above | 43,656 | |
| Yearly Profit | | $64,209 |

would be taken up by electrics which would yield $50.00 a piece a month for pleasure cars, and the following rates for trucks:

| | |
|---|---|
| 1000-lb. capacity | $40 per month |
| 2000-lb. capacity | 45 per month |
| 3000-lb. capacity | 50 per month |
| 2-ton capacity | 55 per month |
| 3-ton capacity | 60 per month |
| 4-ton capacity | 65 per month |
| 5- and 6-ton capacity | 70 per month |

On this basis, an average figure would be around $54 a car for the electrics, at which rate 82 (one-third the net capacity kept filled constantly), even after deducting one-third from the table allowance for rental and for gasoline and oil sales, would add a little over $10,000 to the annual receipts, and only $1200 plus the extra interest of $360 on $6000 to the running expense. The net result, all things considered. would be to increase the rate of profit on the increased investment and over the interest charge to 34.3 per cent. This showed that it would be a profitable proposition to consider the electrics, which had not been given a thought previously.

This is about 32 per cent profit on an investment of $205,600, over and above the 6 per cent interest figured in above Tables I and II.

While these figures represent a big car layout and city conditions, the average which can be worked out from them is not very far off for any kind of an installation. Thus, the original investment of $830 per car housed cannot be lowered very much. Using this estimate as a basis, a garage large enough, say 50 x 110 feet, to house 30 cars would necessitate a total investment of $24,900 or, in round figures, $25,000. Experience has shown that this is not a bit too much. The average income per car is put down at $440 a year, and the average cost of operation per car housed at approximately $100. The income for a typical 30-car layout would give a total of $13,200, and the cost of operation is $3000. It is doubtful whether a 30-car garage could be run on this low basis of cost, which shows the economy of having the larger institution. On this basis, the small garage could have but one bookkeeper and stenographer at $40 a month, and one floor man at the same figure, with the owner acting as both day and night superintendent, washer, etc. On a small layout of this kind, it is a question whether the cost of operation per car would

not run closer to $200, while the revenue per car, owing to the considerable number of small cars, would probably come down as low as $300.

The amount of money to be invested, in addition to the cost of the building and its equipment, should be such as to carry on the business for a reasonable length of time, even without any income. Too many garages have been started without this capital, going on the assumption that motorists had plenty of money and would pay promptly upon receipt of bills. This is not true enough to be laid down as a rule or to be counted upon. So the garage man who is just starting should have enough cash to carry his establishment for several months without any income. It is not urged that the building and lot be kept entirely free and clear, or even that it be owned, but some capital, considerable, in fact, is a necessity.

## TYPICAL EXTERIOR DESIGN

**Building Materials.** It would be unwise to specify any one material as the best, regardless of location, conditions, or amount of money involved, for practically all the materials used for other buildings are used also for garages. Among the materials which are widely used are: wood; steel; wood and steel; concrete in solid or in reinforced forms; hollow tile or other tile, usually stucco covered; concrete, in combination with any or all those given previously; brick; stone; brick or stone combined with any or all the others; and glass combined with any of the others.

The kind of material to use should be selected according to (a) its first cost, balanced against its probable life and depreciation costs; (b) its availability, which is generally governed by local conditions and which has a very large influence upon the cost; (c) its fireproof qualities and their effect upon maintenance charges, through the insurance rates; (d) ease of erection; (e) architectural appearance when completed; and (f) general suitability to the garage business.

*First Cost.* The cheapest material might be the shortest in life so that depreciation charges would be the greatest; on the other hand, the material which was most expensive in the first place might last the longest and thus have the smallest annual charges for deprecia-

tion and repairs. These things have to be considered and balanced one against the other. That form might be said to be the best in any case, which showed the greatest number of advantages in all respects. For instance, wood was formerly a very cheap material. but now it is fast getting out of that class; in certain locations, it is even a very expensive material. On account of its short life, high depreciation, and other drawbacks to be brought out later, it would be a poor material to use. Under some circumstances, however, wood is so cheap that nothing else can compare with it, its first cost being so low as to overbalance its shorter life and greater depreciation. In a case of this sort, wood would be the very best material to use. These same general remarks may be true of many other materials.

*Availability.* Availability has been partly discussed above. When a material is freely available, it is sure to be cheap; whereas a material which is difficult to get is equally sure to be expensive. Beyond being plentiful, availability means also easy to order, easy to have delivered, easy to handle in loading and unloading, easy for workmen to handle and use, and of such a nature that no difficulty will be encountered in getting it to the garage site, regardless of where that may be. All these items count, each one has a value, and in determining the choice of material they should be taken into account.

*Fireproofness.* There is so much gasoline, oil, and other inflammable material around a garage that fire is always a possibility. Garage insurance rates are high and always cut a big figure in the annual running charges of the garage, so that a wise man will consider these in detail before building. Not alone is fire a source of danger to the garage building, but it is also dangerous to the business, and indirectly to the garage man through his customers' cars, as the owners of the cars might sue if a fire occurred. From this point of view, the all fireproof building is the best, but the materials differ. All concrete construction, with metal window sash and door frames, probably comes the nearest to being fireproof; but all brick, with, concrete floors and metal sash and door frames, is almost as good, as is also the hollow-tile stucco-covered form and the stone or structural-iron framework, covered with tile or brick, as well as various other combinations.

Here again, the relative advantages of each material must be balanced, and that one selected which has the greatest number of good points, also the preceding qualities must be considered, as well as those which follow. Thus, in a location where concrete might be admittedly the best on all counts, cement for making it might not be available or, if so, in such limited quantities as to make it difficult to erect such a building. A wooden structure, possessing the merits of being the cheapest, is often made semifireproof by being covered with galvanized iron inside and out, the combination possessing many real advantages despite its crudeness.

**Ease of Erection a Factor.** Ease of erection is somewhat a matter of local conditions. For a contractor who knows his business, no one building is more difficult to erect than another. But there are conditions in which there would be difficulties in the way of erecting buildings, say of concrete, that would put this material entirely out of consideration. It will be admitted that bricks are easier to lay up than stone, so that the former would have an advantage almost anywhere over the latter. In a town lacking a structural iron works, steel or iron as a framework would undoubtedly be out of the question.

**Architectural Appearance.** Architectural appearance has been considered all too little in the past, both as regards the appearance of the material and in the matter of design of the building. With reference to the appearance, it will be admitted that wood does not have a good appearance for garage use, especially when it is covered with galvanized iron, as in the example just given. Sheet steel does not appear well either. Solid concrete does or does not appear well, according to the method of handling. Brick presents a good appearance if handled well, but it can be so handled as to have ugly outlines. Stone usually presents a good appearance; and also the combinations of brick and stone; brick or stone with glass; concrete with brick or stone, or with wood in the form of half timbering; and other forms. In short, almost any form can be made to present a splendid appearance, regardless of the appearance of the material itself in the raw state.

With reference to the general appearance of the garage itself, it cannot be urged too strongly that the garage builder employ an architect and let him design an exterior that will be both simple and

pleasing. Too many garages, like Topsy, have "just growed", and they look it. In going along the road looking for a place to buy some gasoline, or other supplies, 99 motorists out of 100 will stop at the best looking of two garages set opposite each other. Viewed from this standpoint, a pleasing exterior appearance is a commercial asset; it brings in business, therefore it has a value, and should be studied out as carefully as any other point in the garage design or construction that will have an influence on the right side of the ledger.

**Typical Exteriors of Good Design.** In this connection, some sketches of exteriors made from actual photographs of successful

Fig. 22 Pleasing Garage Exterior Lines Produced through Symmetry and Disposition of Windows and Doors

garages will be presented, and the garage man considering the building of a new structure can study them out and see which appeals most strongly and why. Having determined this point, his existing or projected building can be modified to have these lines, in order to bring the same success.

Fig. 22 shows an ornamental and pleasant front obtained by the arrangement of the windows in large and small units. Despite the straight lines, it is regular and symmetrical. The building is of brick, with a front of white-faced brick, on which the name appears

in gold letters. The ground floor is of cement, the second floor double $\frac{7}{8}$-inch Georgia pine laid at right angles. All ceilings and partitions are covered with pressed-sheet steel, enameled white. The roof is flat and has two skylights. It measures 60 x 100 feet and holds 75 cars.

Another brick building is shown in Fig. 23. This is one story higher, and the roof overhangs the third story, giving a pleasing touch.

Fig. 23. Good Garage Front Which Was Brought about by the Use of Tapestry Brick, Concrete, and Tile on Simple Lines

The front is of tapestry brick, with tooled cement trimmings and columns. The roof tiles are semicircular in form and green in color. The building is fireproof throughout, with metal sash and door frames. Such a large part of the building is used for show room and salesrooms that the garage capacity is small.

Fig. 24 shows another brick building in which a considerable amount of glass gives the structure an open pleasing appearance,

Fig. 24. Large High Garage with Big Capacity, Yet of Pleasing Appearance Owing to Neat Lines and the Free Use of Glass

Fig. 25. Ornamental Overhanging Roof Lines and the Rising Central Portion Break Monotony of Straight Lines and Give this Garage a Good Appearance Which Draws Trade

at the same time increasing the interior light in a marked manner. Floors are made of cement. The front shows what can be done with perfectly plain materials and plain straight lines. The garage shown in Fig. 25 is built of brick on a steel framework, while the roof, having many skylights with wire glass, is on steel trusses. The ornamentation by means of the raised center, curved lines, overhanging tile roofs, and small overhanging ledges of red tile above the two symmetrically disposed entrances, all combine to make a pleasing building to look at, and one which the people of the neighborhood would not object to. The floor is made of concrete. The size is 88 x 275 feet, and it houses slightly over 100 cars.

Fig. 26. Tapestry Brick, Symmetry, and Long Low Lines Make This Garage Most Pleasing to Look at and an Ornament to Any Neighborhood

The garage in Fig. 26 is attractive because of its long low lines, its Spanish Renaissance style of architecture, the very large windows on the ground floor, and the symmetrical disposition of all windows, the whole building being symmetrical about a center line. It is faced with tapestry brick, has an overhanging red-tile roof, and is set back 50 feet from the street. The walk is of tapestry brick, the car entrance being on the side street occupying

a prominent corner. The floors are of concrete, the entire building being of brick and reinforced concrete. It measures 162 x 260 and houses over 120 cars, besides giving up the whole front to the offices and showrooms. The rear, or garage, portion is but one story high.

A western garage is seen in Fig. 27, having a bold front of stucco and red tile in the Mission style. Its long low lines, the red tiles standing out from the dead-white stucco, the straight lines broken up by the ornamentation, with just enough curves added, and the symmetrical placing of all doors and windows make it very attractive to look at. The owners did this intentionally, and some one from that city has said of it: "Outside of its service, the bold

Fig. 27. Stucco, Red Tile, and the Ornamental Touches Make This a Distinctive Garage

pleasing front which is in harmony with adjoining buildings and with the evergreen park on the opposite side of the street, is the most valuable asset of the garage." The garage measures 80 x 80, all of which is for live storage except a 12 x 28 office. Forty-five cars are handled normally, but places have been made for 58.

A southern reinforced concrete structure is seen in Fig. 28. It is of a Spanish type of architecture with an overhanging flat-tiled roof. It is on a prominent corner and has three stories and a basement, each measuring 103 feet square, all with cement floors. All the shops are located on the top floor, while a small part of the ground floor is used as salesroom and show room.

**General Suitability of Design to Garage Business.** This means neither more nor less than proper planning. If the building has

been planned for easy entrance or easy exit and has an arragement that gives the washers the least amount of car moving to do, that provides for a large enough office so placed as to have supervision over all cars coming in or going out, with the oil room located where it is easy and convenient to all customers as well as to the workmen, with a location of the fuel tank at a point where it may be easily filled and customers easily supplied inside the garage as well as transients at the curb, and if it has all the other features which will make the garage easy to operate and which also will make for efficiency

Fig. 26. An Example of What Can Be Done with Reinforced Concrete, When Well Designed and Suitably Ornamented

and for a minimum of lost time and wasted steps, then it will be suitable for the garage business. If space allowed, it would be an easy matter to show how any one of these items, if overlooked, can bring about the failure of the business. It will suffice to say, however, that if entrance and exit are difficult, customers will not come in, or having come in once will not come again; if the arrangement makes the washers a maximum amount of extra and unnecessary work, it will be difficult to get them to do their work thoroughly, and customers will be displeased and will go elsewhere; if the office is too small, or so located that the incoming and outgoing cars cannot be observed,

there will be large losses; if oil and gasoline are not quickly accessible, people will go elsewhere to buy their supplies of these materials; so too, with many other features which might be mentioned, and, if these things are not well studied out in advance and provided for, it will not be possible to run the business on an efficient profitable basis.

## NECESSARY EQUIPMENT FOR GARAGE

**Major Equipment.** Ordinarily, a person thinks of equipment as tools, supplies, and other means of doing work, but these might almost be called minor equipment in comparison with the major equipment. Major equipment might be listed as *lighting,* both natural and artificial; *heating,* which almost always means the individual heating plant for the garage, as there are few cities where heat, like electricity or gas, can be bought; *ventilation,* which may be incorporated in the building in part, or it may mean fans, blowers, and the like, in addition to those means which the building provides; *water supply and provision for washing,* in which the water supply may mean the installation of a pump, the provision of a special tank, power for driving the pump, etc.; *drainage,* which is closely allied with ventilation, for means must be provided for taking care of the fumes from gasoline, oil, kerosene, etc., which are dangerous and must not be allowed to reach city sewers; *provision for power* to drive machine tools, tire pumps, vacuum cleaners, buffers, etc.; *an elevator or a ramp* and a turntable—provision for moving the cars up and down, if there is more than one floor, or around the garage; *fuels and oils, greases*—in liquid form and in cans or packages—*and waste;* benches, lockers, cabinets, racks, stands, and other similar things which might be called garage furniture; and, finally, *tools,* both large and small.

**Lighting.** *Natural Light.* The interior width of the garage has a large influence on the number of windows needed for natural, and the number of lights needed for artificial, lighting. The narrower the garage, the easier it is to light it adequately by means of windows set close together on the sides of the building. But, as it widens out, the dark zone in the middle of the building becomes greater and greater until the point is reached at which artificial lighting is needed all the time, day as well as night. One of the axioms of building should be to keep the width down below the point where artificial lighting must be used day and night.

The location of the lot on which the garage is to be built, that is, whether it is between other buildings, on a corner, facing on three streets, running to an alley, etc., is important as regards the lighting, for plenty of natural light will be available in all these locations except in the first. The location in a downtown part of a large city has an unfavorable influence on the lighting situation, for it is almost a certainty that the light will be obstructed in one or more directions. The necessity for going higher up in the air, that is, building several stories high, brought about through the value of the land, makes a garage darker than would be the case otherwise. With a one-story building, many large skylights can be used, and these supply excellent light. An irregular shape is difficult to light if it is large; on the other hand, if it is small, it is very likely to have a greater area of outside walls relative to its interior or car space than would a regular shape and thus an opportunity for more windows than would ordinarily be the case, which would reduce the necessity for excessive interior lighting.

*Artificial Lighting.* The garage man should study out all these things so as to get the maximum amount of natural light, for that costs nothing, and to use the minimum amount of artificial light, for that is expensive. Electricity is the only satisfactory form of artificial lighting, all other forms having an exposed flame which will ignite gasoline and oil fumes. If a supply of electricity is not available, a small self-contained plant, with a gas engine and a generator set proportioned to the number of lights needed, and a set of storage batteries to equalize the supply and demand should be installed.

There is a wide difference of opinion as to the number of lights needed. The writer would say that the equivalent of one 16-candle-power lamp is needed for each four cars. These lights need not be installed in just this way, but they can be grouped in threes, fours, fives, or sixes in such a way as to give a better total effect than the single bulbs strung out would give. In a large garage with sufficiently high ceilings to admit doing it to advantage, arc lights can be substituted, on some such basis as one arc light to a very small floor, two to a small medium size, three for a medium or large size, and others according to the size of the garage and its needs. It is generally advisable to have very good light around the wash rack, as most of the washing in city garages is done at night.

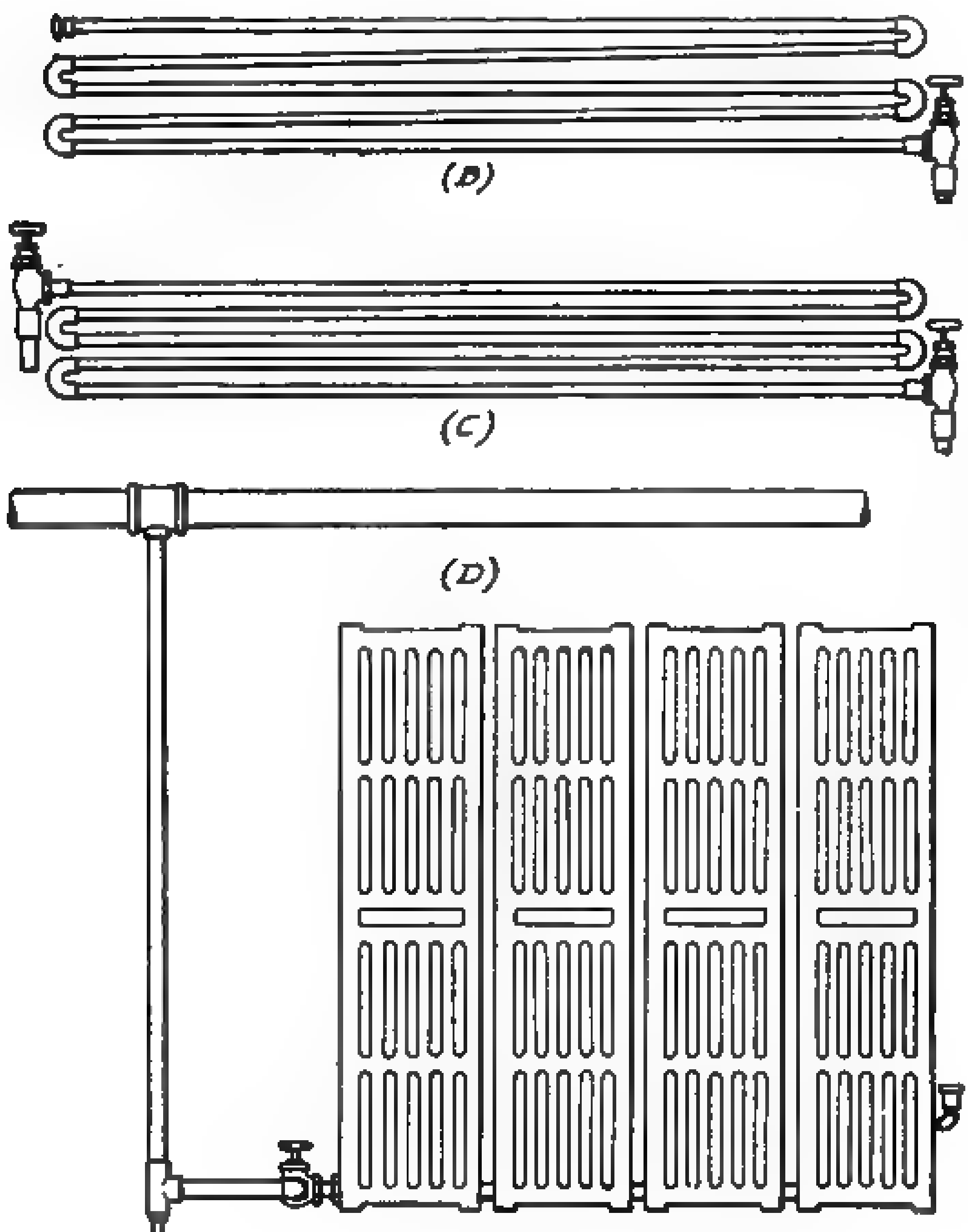



Fig. 20. Four Methods of Piping a Garage for Heating Purposes

**Heating.** The idea of heating the garage is not alone to keep the water in car radiators from freezing, as many garage men seem to think, but also to make it a comfortable place for workmen and car owners to come into or to work in, and to keep the cars at such a temperature as will allow quick and easy starting. Many kinds of heating plants are available, but steam or hot water are the best, for with either of these the heat can be used to warm the water for washing the cars, thus making washing easier and quicker. If a lighting plant is necessary, the exhaust from the engine can be utilized, whether it be steam or gas. The exhaust may not be sufficient of itself, but it can be used as far as it goes, effecting a considerable saving. When either steam or hot water is used for heating, the radiators are generally made up of pipes, or else a wall radiator is used. A specially thin form for this purpose may be had. The radiators can be put in one of three forms, viz, pipes to and from a header, as at *A* in Fig. 29; return bends, which may be either single, as seen at *B*, or double, as shown at *C*; and the wall radiator, shown at *D*.

**Ventilation.** In a small garage, a ventilator on the roof, or two windows opened so as to create a draft through the building will suffice generally, but in a large garage it is advisable to provide a form of fan or blower, the fan to draw out the air, and the blower to force in fresh air. Either one can be placed in the upper sash of a window; so no special place need be provided. The open doors with their large area, the elevator shaft or the ramp, and the big open space of the interior generally make ventilation easy, but it is desirable to provide some mechanical means of changing the air and thus of being on the safe side. This is doubly necessary, for the vapors from gasoline, kerosene, and oils are explosive, while the exhaust gases are poisonous.

**Water Supply.** For the city garage, water supply is simply a question of proper pipe connections and prompt payment of bills, but in the country it may mean much more. It may mean, for instance, the boring of a well before starting to build the garage and the installation of a pump to draw the water up from this well and force it to a large overhead tank. All this costs extra money. In planning the water system for a garage, it should be borne in mind that the water is used not alone for washing, for use in toilets, and for other personal uses, but it is also used for filling radiators, so

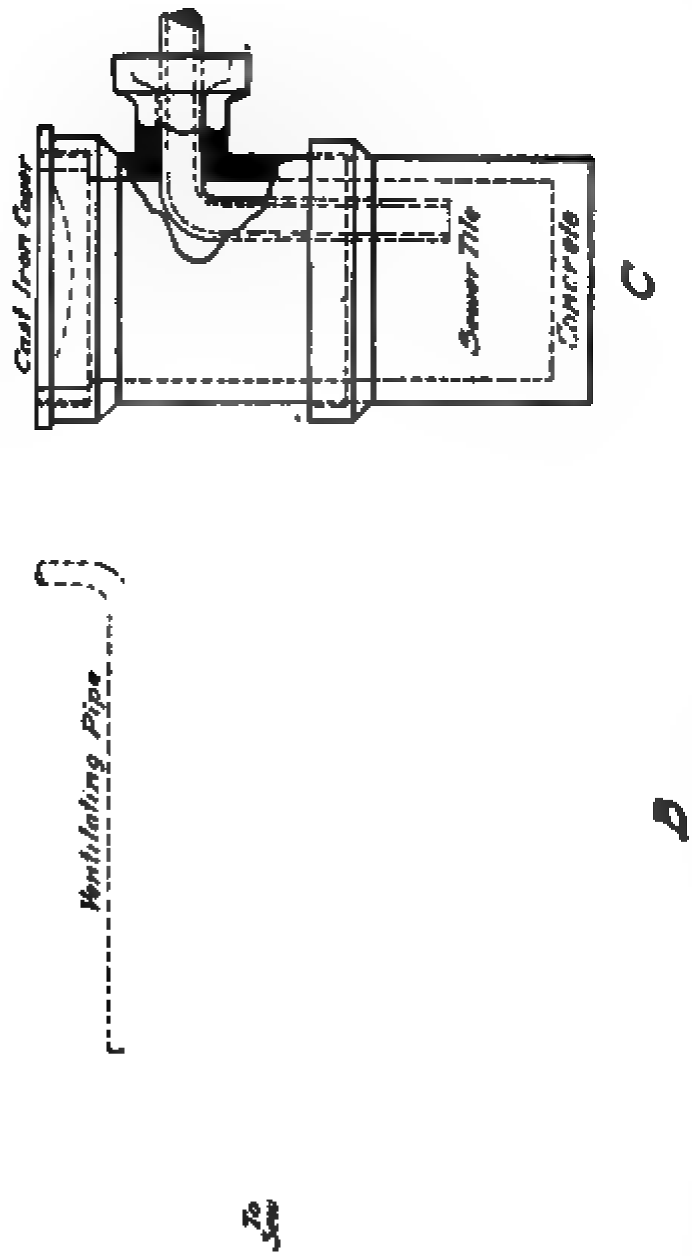



Fig. 30. Three Different Kinds of Efficient Garage Drains

that a pure water without too much free lime is needed. The water system also forms a large part of the fire protection of the garage and should receive adequate consideration.

**Drainage.** Garages need good drainage to carry off the water used in washing the cars and to carry away the gasoline and oil drippings from the engine, transmission, axles, and other parts. The best way is to give the cement floors sufficient pitch to carry off the heavy stuff, and the drainage for the water will be very good. The arrangement should be such that all drainage will flow into a trap, or into several traps. Gasoline will float upon water and will vaporize while laying upon it, while oils, greases, etc., will sink. A water seal on the trap, with a ventilating pipe connecting the surface chamber to the roof, carries off the vapors, while the heavier materials will sink to the bottom and will accumulate. Several

forms of traps are shown in Fig. 30. At *A* is shown a cast form, which is very rugged and is provided with both a ventilating pipe to the roof and a safety air space around the sewer pipe. At *B* is shown a homemade trap of concrete and of iron pipe. At *C* is shown another homemade form constructed from two sewer tiles, one with an L-outlet, with cement to close the bottom, and a cast-iron cover for the upper one.

**Provision for Power.** If there is to be a machine shop, power must be provided, but even if there is no machine shop, there is generally a need for some power, as for the driving of the water pump, of the ventilating fans, of the air compressor, or of other units. If a lighting outfit is a necessity, it can be so arranged as to supply small amounts of power, either directly through belting, shafting, and pulleys, or indirectly in the form of electricity to electric motors. The indirect method is the preferred way, for it is simpler, cleaner, neater, more economical, and more up to date. If the garage is supplied with electricity, the question of power takes care of itself; in fact, it may work to reduce the lighting cost, as current rates are generally based upon the quantity of electricity used, the lower rate being given for the greater quantity.

**Provision for Moving Cars.** The subject of elevator versus ramp has been discussed previously and will not be repeated here. The garage of more than one story must have one or the other means of moving cars up and down. In addition, all large garages should have turntables, as these save a great deal of time and space in arranging the cars in their places, and in getting them out when needed. By referring back to the illustrations previously shown, it will be noted that a number of the larger garages had a turntable provided on each upper floor, and two on the ground floor, all being in front of the elevator. This enables turning the car as it comes off the elevator or before putting it on so that it points in the desired direction. The elevator at the back of a building must have a turntable to work with it, for every car would come in frontwards, and if it went on to the elevator that way, it would have to be backed off and, unless there was a turntable right there, backed to its place. Similarly, when being taken out, it would come to the elevator front end on, and when it reached the ground floor, the owner would not want to back it out. In such a case, a turntable saves double trouble with each car every time it comes in or goes out.

**Fuels and Oils.** Nearly all fuel systems nowadays are of the buried-tank type, with surface pumps. These systems have developed through the need of having the gasoline tank out of the way and protected from harm, also where it could be very large and consequently have a big supply. When it is considered that a car can easily use from 5 to 10 gallons of fuel a day, with the average around 7, it is easy to figure what supply a 100-car garage needs to have, namely, 700 to 1000 gallons per day. When transient trade is added to this, such a garage should have provision for close to 1800 gallons

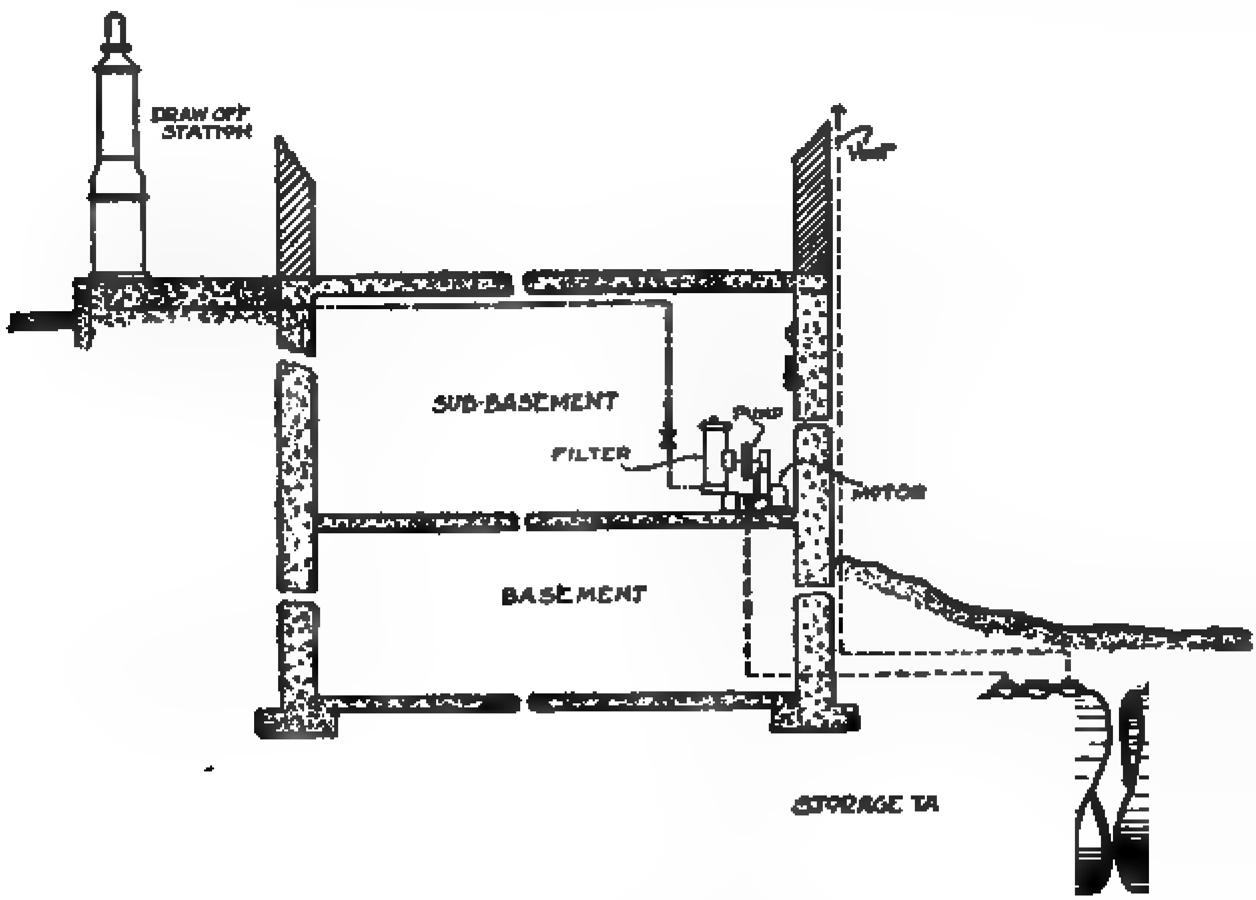



Fig. 31. Bowser Remote-Control Fuel-Supply System
*Courtesy of S. F. Bowser Company, Ft. Wayne, Indiana*

a day. The mere handling of this amount is sufficient to keep one man busy, but, as it is profitable, the garage man should provide for it. Many systems are now in use, the most popular for large installations being like that shown diagrammatically in Fig. 31. Here, the tank is underground, outside of the building, while there is a pump in the basement, which is operated by an electric motor. This motor is set in motion by a lever at the curb stand, or draw-off station. This same general layout, but without pump and motor, is used in those systems in which the liquid is actually pumped by hand, through the rotation of a handle.

For use in and around the garage, it is desirable to have a smaller portable tank and pump, like that shown in Fig. 32. This tank has a capacity of about 50 gallons and makes it possible to fill cars wherever they are located instead of forcing the driver to come to the pumping station. This often saves time, as the attendant can fill the tank while the owner or driver is doing something else. It has been found to be both handy and economical in large garages.

Fig. 32. Portable Supply Tank for Use in and around the Garage

The garage man who desires such a form of underground gasoline tank, but cannot afford to buy one, should buy the components and make one. Such an outfit is shown in Fig. 33, although this one has a limited capacity. The tank must have three openings—filler, suction pipe, and pressure pipe. These are marked *F*, *D*, and *B*, respectively, in the cut. A large pump supplies the air pressure which forces the gasoline upward through pipe *D* when the cock *E* is opened.

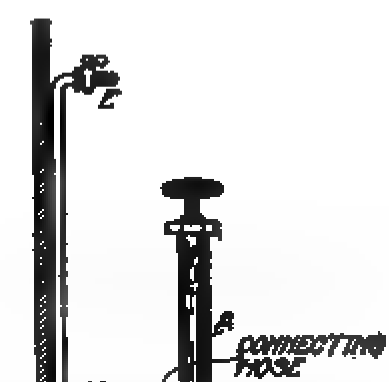



Fig. 33. Simple Arrangement of Outside Fuel Tank

For handling oils, a different form of pump is needed. Oils are generally kept in a special oil room, and the different qualities are kept separated. Moreover, in comparison with gasoline, small

quantities of oil are sold at a time. Aside from the fact that the receptacles are small and do not have wheels, the oil-supply system usually resembles a battery of units, like that illustrated in Fig. 32.

**Air-Supply System.** Thus far, no mention has been made of a source of air supply, which is very necessary. Air is constantly in demand for inflating tires, and no up-to-date garage should be without it. In addition, it is handy for cleaning upholstery, for cleaning off repair parts, and in many other ways. The general

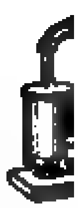


Fig. 34. Four Different Air Supply Systems in General Use

sources of supply are hand (or foot) power, which is inadequate for a large garage; electric power; and a belt-driven or engine-driven air compressor. Fig. 34 shows these three forms at *A*, *B*, and *C*, respectively, while at *D* is shown the steam-driven form, which is similar to railway locomotive compressors, and is a very efficient and compact form for use in large garages. Air compressors are now made in small sizes and mounted upon wheels, with electric-motor drives and lamp-socket connections, so that they can be wheeled around the garage to the desired position, then started and air supplied as desired.

**Garage Furniture.** The garage has need for many articles of wood and steel, such as engine stands, work benches, lockers, etc., which cannot be described by any other name. These are really necessary; and the garage without them is not adequately equipped. In addition to the necessities in this line, there are of course many more which are desirable, which save time and space, and which are supposed to save money too. Also there is much of this kind of stuff that the handy man can make himself, that is, given enough equipment and furniture to start the garage, the handy man can make additional furniture and equipment as the demand arises, thus gradually improving his place without much expense. The necessary furniture will be described first.

There are so many different bolts, screws, and nuts around an automobile that a supply cabinet for these articles is a prime necessity. One of the best of these cabinets is shown in Fig. 35. It consists of an eight-sided cabinet, each side of which has twelve drawers, so that a total of 96 drawers of small size are provided in a very small space.

Fig. 35. Useful Revolving Cabinet

Practically the same thing, but in a different form, is the type of cabinet shown in Fig. 36. This has a large number of small drawers arranged in a horizontal plane. The form shown at the left is made with 54 drawers, the one at the right with 60. The case has a steel back, the drawers are made of galvanized steel and are dustproof. The larger drawers at the bottom are made with removable partitions. A pair of these cabinets set back to back make an excellent combination for a good size garage. The general run of drawer size in this form is so much larger than that shown in Fig. 35 that it would be possible to utilize both in the same garage,

the one shown in Fig. 35 for small bolts, nuts, cotter pins, and similar very small parts, and the one shown in Fig. 36 for much larger parts.

Other ways of producing the same results are by the use of made boxes, the idea being to purchase a supply of these boxes to suit present needs and to erect shelving to fit the boxes bought; then, as more boxes were bought, more shelves could be erected. These boxes are really well-made drawers, with locked corners, and are made in interchangeable sizes so that one large, two medium, or three small, or still other combinations may be used on the same shelf. Unit steel

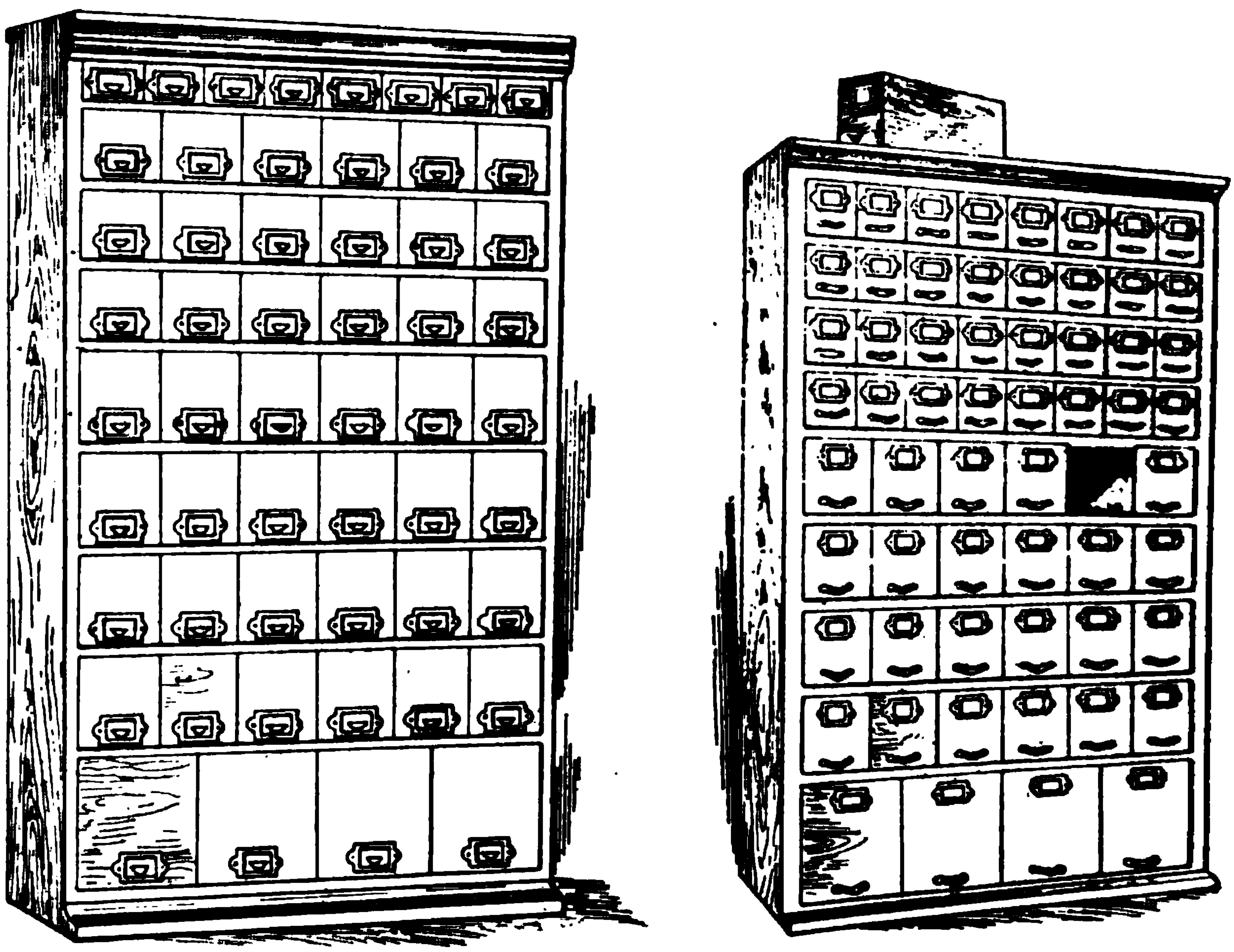


Fig. 36. Excellent Type of Plain Cabinet for Small Parts, Bolts, Nuts, Etc.

shelving is also used, the steel shelves, with drawers, if desired, being made up in a variety of sizes and shapes to fit the various needs. They are built on the unit system, so it is possible to buy a few for a start and add others as the business grows.

Besides the cabinets for automobile parts are the lockers in which customers may hang their clothes, etc., and the various racks and shelf brackets or salesroom fittings to display and hold the various accessories which the garage sells. They may be made in any shape, homemade fittings being very serviceable, but the lockers are generally

made of steel. They are made in two forms, both of the same height outside. One form has the full height per locker, while the other is divided in the center, thus giving two lockers each of the half height. Both forms are made in several widths.

**Work Benches.** The work bench is an important adjunct of the garage, and in every garage, unless it be a city place with a repair shop in connection, a work bench will be found at least along one wall. They almost always have a wood surface, usually of about two-inch lumber, but the framework is of wood and steel. The wood form is easy to make or to have the carpenter make, as it consists simply of a

Fig. 37. Garage Interior Showing Model Work Bench Layout and General Arrangement

framework of four-by-four timbers, with a top of two-inch lumber and a facing, or corner board, of one-inch stock, and a tie, or brace, of about one by six stock below and close to the ground. If the bench is carefully designed, there will be a shelf underneath it for small boxes, and a series of these boxes will be made for small parts, replacing, in part, the cabinets spoken of previously. There should be one or more large drawers, also shelves or racks on the wall behind and above the bench. The bench height varies from 2 feet 8 inches to 3 feet, but 2 feet 10 inches is about the average. An excellent example of this, although made with cast-iron supports for the ends, is that shown in

Fig. 37. This shows not only the size, shape, and arrangement of the bench, but also the size and disposition of the drawers, location, and arrangement of the fixed and swivel vises, and the arrangement of the other tools and parts. Maple and birch are considered the best woods for benches.

Fig. 38. Zinc-Lined Washing Bench, Which is Very Useful When Disassembling Cars
*Courtesy of "Motor World"*

For cleaning parts, a special bench is desirable, and this should be lined with zinc, by preference, and have a tapering or sloping surface. It should be low, and should be provided with a drain so that oily parts can be deposited on the drain and the oil cleaned off and saved. The oil can then be filtered, and the better parts used again. Such a bench is illustrated in Fig. 38, which shows all of its construction, unless it is the braces needed underneath to stiffen it. These braces are desirable, for the bench often holds a very heavy load of parts. By making the squared section of the drain large, frequent draining is avoided.

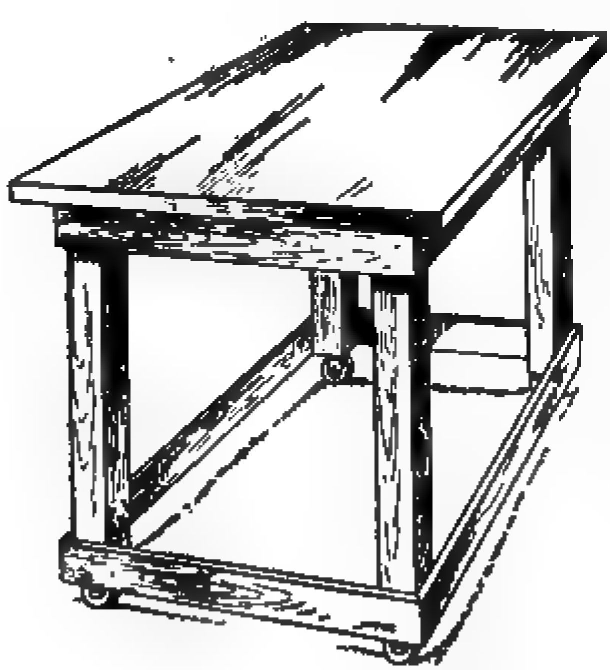


Fig. 39. Small Work Bench on Casters, a Very Handy Device

A further necessity in a garage is a small bench on wheels or on casters, stout enough to work upon, but not too heavy to be easily moved around. It should be a few inches lower than a regular work bench, which will also facilitate moving it about. Such a bench is very handy when disassembling or assembling a car or some of its units, since it gives a place to lay the parts as they are taken out, or to lay them out in the order in which they are to go together again, as well as a place on which to lay the tools which are being used. Sometimes

these tables are made with a drawer and are oftentimes stout enough to carry a vise attached to the working surface. The simplicity of the construction of one of these benches is shown in Fig. 39.

**Special Stands for Units.** Where the nature of the work is such that a good many units of one kind and size from some one machine

Fig. 40. Handy Form of Engine Stand Constructed from Piping
*Courtesy of Shewalter Manufacturing Company, Springfield, Ohio*

are handled, it is advisable to have special stands made for them, as, in so doing, much work and trouble can be saved. Several such stands are shown in Figs. 40, 41, and 42.

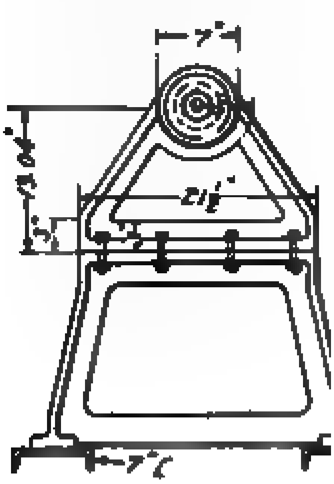


Fig. 41. Engine Stand Which Allows Motor to Be Turned to Various Positions

A portable unit-motor stand made of tubing is shown in Fig. 40. The oil drip pan and shelf arrangement at the open end are features. The disadvantage of this form, however, is that the unit motor sets

only in an upright position. This makes work on the crankshaft bearings and other parts on the under side of the motor difficult.

A stand which will hold the engine unit in various positions is shown in Fig. 41. It is made by the International Motor Company, of Plainfield, New Jersey, for its own use, and is an excellent but expensive stand.

A pair of stands are shown in Fig. 42. *A* is made of pipe fittings and angle irons and can be adjusted to the transmission or to the engine. *B* is a specialized stand for transmissions. The stands in

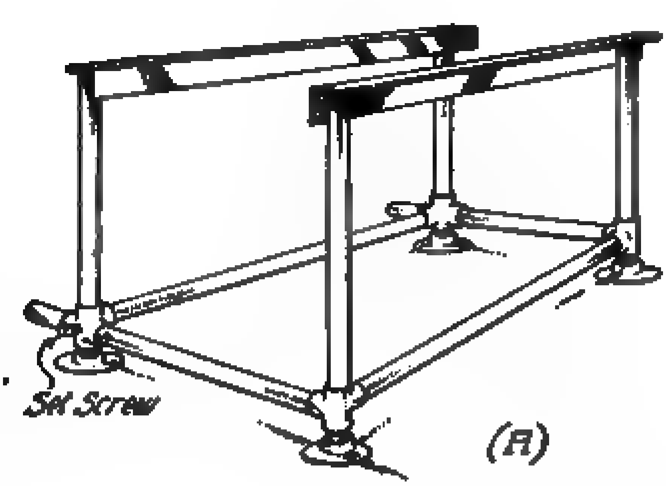



Fig. 42. Two Types of Handy Transmission Stands

this figure have the disadvantage of holding the units in an upright position only.

## GARAGE TOOLS

The tools for use in the garage may be divided into two general and widely different classes, hand tools and machine tools. In the former class come all those tools which are used, but which require nothing but hand power to drive them. In the second class come all those tools which garages have or should have, but which require power to drive them.

**Hand Tools.** In the way of hand tools, which are too widely known and used to need any description, are: hammers, chisels, files, scrapers, punches and drills, clamps, reamers, taps and dies, measuring instruments, screwdrivers, saws (for wood), brace and bit, hack saw, jacks, wrenches, vulcanizers, breast drill, blow torch, oil stones, snips for cutting sheet metal, oil can and oilers, kit tire tools, spring leaf spreader, pliers, etc.

*Vises.* Vises as a means of holding work are very important and come under the heading of hand tools. While there are a number of different types, only two are used regularly, the plain bench vise and the swivel type. With the former, the jaws can only be opened or closed, but with the latter, the whole vise, including the work, can be revolved to a more convenient position. In addition, the latter type has a swivel jaw, a big advantage in gripping tapered work. By means of the locking pin at the right end, the jaws are fixed in a parallel position.

**Machine Tools.** The garage which does any work upon cars will soon require a few machine tools. This statement applies to the small shop that would not undertake regular machine work under any conditions. Such a shop should have, as a minimum, a lathe, a drill press, an emery wheel or other grinding means, with perhaps an electric motor having buffing and grinding attachments and of a portable type so as to be capable of use anywhere in the shop.

*Lathe.* Of these tools, the lathe is the most important, and the small garage man with limited capital should pick this out with great care. It should be as small as will handle his work, although some of this work, notably flywheels and clutches, will require an 18-inch size. This fact immediately brings up a point which the garage man should decide in advance, and that is whether he will handle this big work or send it out. If he decides upon the latter method, his lathe size can be limited to a 10- or 12-inch machine. From a garage man's point of view, it is to be regretted that no manufacturer has ever seen fit to bring out a special model for this class of work, as there should be a market for hundreds of them. What a garage man needs is a two-purpose, or two-spindle, or gap-bed type of lathe, which would give a maximum capacity of 12 inches for all normal work, perhaps 360 days in the year, and a greater capacity, say up to 18 inches, for use one or two days a year, as for flywheels, clutches, brake drums, etc. A lathe of this kind is not made, however, so the next best thing is a high-quality plain engine lathe.

*Lathe Accessories.* With a lathe, a considerable volume of accessories are necessary for handling a variety of work. It is advisable for the garage man to go slow in the purchase of these, until the nature of his work has shown the necessity for them. By this, reference is had to the various compound gears for screw cutting, different forms

of face plates, center and steady rests, chucks, mandrels, tool holders. tool posts, taper cutting attachments, tool grinders, boring heads, and other things.

*Drill Press.* Drill presses are of three kinds, generally speaking. the sensitive drill which is too small and delicate for the range of average garage work, the usual drill press, and the radial type. The garage has little or no use for the latter type, nor for the modification of the standard form known as the multiple-spindle drill. A plain stout drill spindle which is made to a size that will handle drills up to and including $\frac{3}{4}$ inch is all that is needed.

*Emery Wheel, or Grinder.* The nature and quantity of the work would determine the size and quality of the grinding wheel to be used. A plain rotating emery wheel can be used for so little, while a properly selected grinding wheel can do so much work that is almost machining and, in this way, replace, perhaps, a planer, a shaper, or a milling machine, that the garage man should make his choice very carefully. It is a very handy tool, with many advantages over the ordinary emery wheel using the edge only for grinding.

Fig. 43. Typical Power-Operated Hack Saw with Changeable Stroke Feature

*Hack Saw.* The power-driven hack saw is an inexpensive tool, and even the smallest garage finds sufficient work to warrant its cost. It is useful for cutting all kinds of material into lengths, as, for instance, bar stock in square, round, or other form. It works almost without attention and will do more than three times as much work as a man with a hand hack saw can, do it much quicker, more neatly, and better in every way. In Fig. 43 is shown a power hack saw, which may be taken as typical, although there are many different sizes and styles. A feature of this saw, which is not common to all saws, is the adjust-

able stroke. The disc which drives the saw is slotted, and the driving bolt in this can be set in various positions. When set as far out as possible, it gives the longest stroke, and when set close in to the center, it gives a very short stroke.

One thing needed for, or rather with, a power hack saw is an outboard support for long work. Such a stand is shown in Fig. 44. It is simple and is easily made.

Fig. 44 Outboard Stand for Hack Saw Facilitates Handling Long Stock

Of almost greater necessity than the stand is a stop for the saw, or a power shut-off which will work when the cut is finished. Normally, a power hack saw is started on its work and left. In the press of other work, this work is often forgotten, and the saw completes it and then continues sawing idly at the air. To give a signal the device shown in Fig. 45 may be used; this consists simply of an electric bell connected to a dry cell in such a way that the dropping of the end of the work pulls the switch, thus closing the circuit so that the bell rings. When the work is put in and the saw started, all that is necessary is for the workman to attach the string to the end which is to be

cut off, with the switch open, taking care to have the string tight enough so the dropping of the piece will open the switch.

Fig. 45. Simple Electric Signal Applied to Hack Saw

*Grinding in the Lathe.* Many a shop owner does not feel that the cost of a separate grinder is warranted by his work, even though he does have quite a little grinding to do. When this is the case, a grinder can be rigged up on the lathe. This is done as shown in Fig. 46. The large pulley on the line shaft and the small pulley at the grinder give a sufficiently high speed. The lathe ways form a support for the work if it is large, while the carriage feed and cross-feed give a movement of the grinding wheel along or across the ways as needed.

Fig. 46. Method of Rigging up Grinder on Lathe
*Courtesy of "Motor World"*

*Milling in the Lathe.* In using the lathe for milling purposes, the cutter is mounted on the spindle, and the work is placed in a special fixture which will allow an up and down movement. The carriage travel carries the work up to the cutter, the cross-feed allows feeding it across the face of the cutter, while the fixture gives an up and down feed. By this means, a considerable range of flat surface work can be done.

*Utility of Portable Electric Motor.* Mention of the utility of the portable electric motor in the small shop has already been made, but

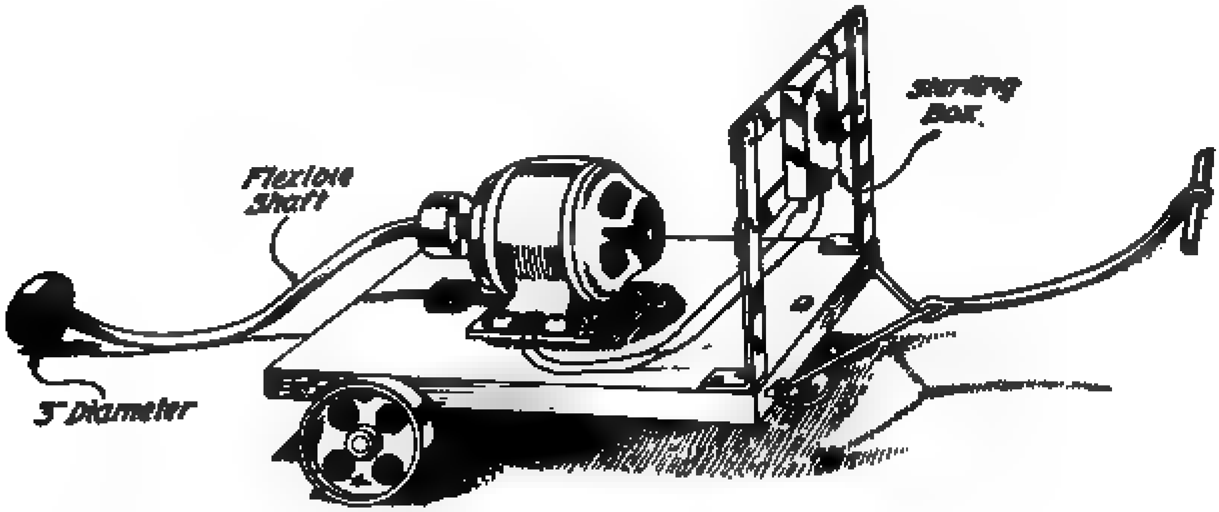



Fig. 47 Arrangement of Portable Electric Motor on Truck
*Courtesy of "Motor World"*

this subject should be emphasized. When a small portable electric motor is properly rigged up and used to its full extent, it is surprising how much good work and what a diversity of work it will do. For grinding, buffing, and similar work, the motor, with a flexible shaft, should be rigged up on a movable truck about as shown in Fig. 47. When the drilling must be exact, the motor can be mounted in a special vertical stand as shown in Fig. 48.

### Tool Equipment for Larger Shops

**Additional Tools.** Usually the larger and more pretentious shop will have a fully equipped repair shop. Such a shop would have all of the

Fig. 48. Framework Which Allows Using Portable Electric Motor as Drill Press

tools that have been described, with their various attachments and accessories, and also a number of larger machine tools, which are necessary and are economical, or time saving, on larger or more complicated work. Some such tools are the planer shaper milling machine; milling cutter grinder and other special grinders, as crankshaft and cylinder grinders; and arbor and other presses, etc. As these are in all respects identical with those found in any machine shop, no further explanation of their uses is given here.

*Other Tools.* There are many other machine tools, but they are mainly modifications of the basic types which have been mentioned. Moreover, the garage man is not interested in them because they are high priced, and are not particularly adapted to his work. The main things the garage man should have in mind when buying machine tools is adaptability to his work and the necessary volume of work to warrant the expenditure. If all garage men would purchase their tools on this basis, and this alone, they would avoid much useless expenditure and equally needless extra overhead charges on account of idle machines.

CUTTING SPROCKETS WITH MULTIPLE-SPINDLE GEAR HOBBER

*Courtesy of Gould and Eberhardt, Newark, New Jersey*

# SHOP INFORMATION

## INTRODUCTION

**Importance of Shop Equipment.** The average garage or repair shop should be equipped to do any repair job which comes into the shop. Of course, the demands in different districts vary somewhat, but a study of the requirements will guide the management in the installation of the equipment necessary. This article is intended to cover the more common bench operations and the operations performed on the various machines which are most necessary. In the article on Building, Equipping, and Running a Public Garage, other suggestions as to equipment of tools and machines are given. In still another article on Welding in Automobile Repair Shops, practical instructions for welding various metals and various parts of an automobile are given.

## BENCH WORK

**Work Bench Design.** As a large portion of the repair work in a shop is bench work, the height, width, and equipment of the work bench should be carefully considered. The machinist's bench at which hand work is ordinarily performed should be of substantial character, about 2 feet 10 inches from the floor and 2 feet 3 inches wide, Fig. 1. For the sake of economy it is usual to have a 2½- or 3-inch plank at the front to which the vises are fastened and on which all the heavy work is

Fig. 1. Work Bench
*Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island*

e bench is by

done, while the rear of the bench is made from 1-inch lumber. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

**Work Vises.** In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a vise. They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 2, shows these parts clearly and also a device,

Fig. 2. Simple Bench Vise

present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out of the nut.

In the machinist's vise both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 2, although a swivel base is really preferable. Vises of this kind often have swivel jaws as well, which enable them to hold tapered work securely. This swivel jaw is provided with a locking pin, which fixes the jaws in a parallel position. The height of the vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaw about 1½ inches below the point of the elbow when standing erect beside the vise.

## CHIPPING AND FILING

**Chisels.** One often hears the term "cold chisel mechanic" used in derision, but the man who can by the use of a hammer and hand

Fig. 3. Methods of Using Chisels on Bolts and Nuts

chisel remove metal neatly and without marring the adjacent parts is a really good mechanic. The term came from the common practice in the early days of the automobile of tightening nuts in place with a cold chisel, which, of course, scarred the nuts very badly. This practice was more the fault of the maker than of the mechanic, as there were places on the automobile where a wrench could not be used. But this difficulty has been corrected on modern cars, and there is now practically no excuse for the use of the cold chisel in this manner.

It is often necessary, however, to remove interfering lugs, etc. when fitting accessories to a car. This is especially true when putting ignition apparatus, lighting and starting equipment, and other attachments on Ford cars. In cutting soft steel with a hand chisel there is little danger of doing damage except by cutting too deep or letting the tool slip, but in cutting cast iron, cast aluminum, and cast brass, which are the metals usually encountered on the motor car, there is great danger of cracking the adjacent part in case deep cuts are attempted with the necessarily heavy hammer blows.

A survival of the old cold-chisel-mechanic days is found in the method of removing nuts. In these days such practice should seldom be necessary around the engine, but it does sometimes happen that nuts on the muffler and other chassis parts become so badly rusted in place that they cannot be removed by a wrench even after the kero-

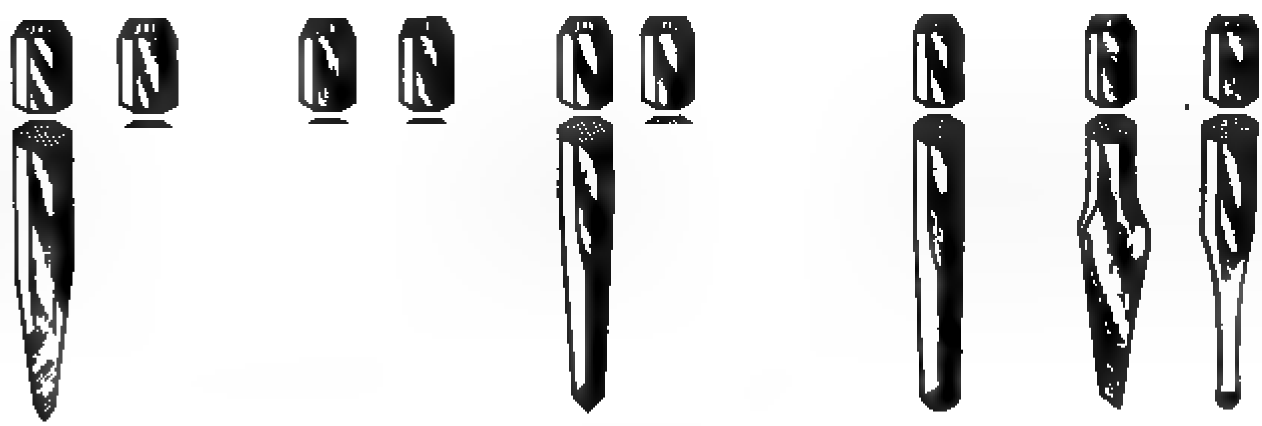


Fig. 4. Common Forms of Hand Chisels

sene-oil treatment. The first thing is to try to start it with a dull chisel at *A*, Fig. 3, but if this does no good and it is desired to save the male member, the nut can be split as shown at *B*. If it is on only an ordinary bolt that can be renewed from stock, it is easier to sheer the bolt, as at *C*, Fig. 1.

Cutting keyways by hand and putting oil grooves in anti-friction metal bearings are the other two uses made of the cold chisel by the automobile mechanic, and these subjects will be taken up in detail later.

**Chisel Types.** Common forms of hand chisels are shown in Fig. 4 in the following order from left to right: flat, cape, diamond, and two types of round nose.

*Flat Chisel.* The flat chisel is the most used and works best where the surface to be cut is of less width than the edge of the tool. It is

beveled on both sides, an included angle of 70 degrees being best for cast iron, while 60 degrees seems best on wrought iron and steel.

*Cape Chisel.* The cape chisel is a narrow chisel with the sides ground back so as to give clearance to the cutting edge in a channel. It is used particularly for cutting keyways and for making channels in a large surface preparatory to using a flat chisel.

*Diamond Point.* The name describes this tool, which is used for cutting sharp-bottomed grooves and for putting holes in sheet metal. It has little application in automobile work.

*Round Nose.* Round-nose chisels, some very small, are of great importance in cutting the oil grooves in babbitt and die-cast bearings. These are often made with curved shanks.

**Chipping.** The ball-peen hammer seems best balanced for the chipping process, and the size of the hammer should be consistent with the chisel being used and the class of work in hand. Warning has already been given against unnecessarily heavy blows on any part of iron, aluminum, or brass casting, because these metals are very brittle. Only the cutting edge of the chisel should be in contact with the work, the lower bevel being at a slight angle. For a deeper cut the shank is raised, and for a shallow cut the lower bevel should almost touch the work. The general tendency is to raise the chisel too high and thus drive into the piece instead of making a good cut.

## Filing Methods

**Types of Files.** The greatest time-saver in filing, as a feature of bench working, is in the selection of the correct file for the work at hand. It is therefore imperative, if a shop is to be at all efficient, to have a stock of files which will take care of every kind of work. Although there are a great number of shapes and sizes available with every imaginable type of cutting surface, those most commonly used are the flat file, hand file, warding file, square file, triangular file, half-round file, and the round file.

You can obtain a file which will cut across one angle of the file or one in which the cutting surfaces cross each other. These are known as single or double files. Different materials to be worked on require different coarseness of the cutting surfaces, and there are five general grades most suitable for general work: coarse; bastard; second cut; fine, or smooth; and superfine, or dead cut.

**File Shape.** In files of fine cutting surface, the length is much shorter than in files with coarse cutting surface. The reason for this is obvious, inasmuch as in heavy cutting one needs a long clean sweep where plenty of muscular effort may be applied to the best advantage; while in fine cutting where the work is more delicate, one needs a file which is light and easy to handle.

Properly constructed files have a very slightly convex surface in the direction of their length. The reason for this is that a perfectly flat file surface, digging-in to the full depth of its cutting ability, presents too much cutting surface to be handled by manual power. With a convex surface, however, the file is first applied at the center of the cutting surface, and this bites into the metal, allowing the rest of the file to be carried in easily. This convexity avoids dulling the cutting teeth, for it prevents frequent skimming strokes over the

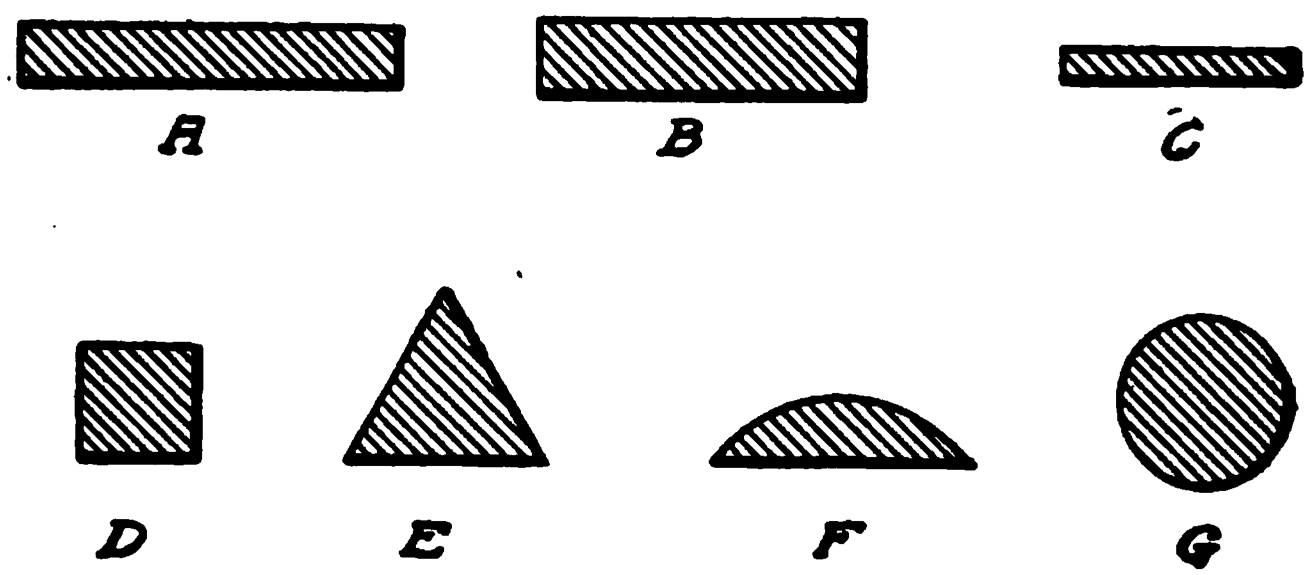



Fig. 5. Sections of Different Types of Files

surface of the metal which, as they apply only the sharp edges of the file, quickly breaks them down. This is naturally not the case when the teeth are deep into the metal. Another purpose which this convex surface serves is to compensate for the bending to which a file is naturally subjected when pressure is applied to it. Although convex in its natural position, the bending action of the file, due to its pressure after the teeth have cut in, very nearly makes up for the convexity. This is, of course, not an accurate compensation.

**Proper Files for Certain Work.** Before discussing the proper methods of handling files, it will be well to discuss the kind of file to select for a certain work. This is a matter upon which no fixed rules can apply. One mechanic may do a certain job with a long coarse file, where another may do the same job in equally quick time and as well with a finer cutting surface.

Generally, however, the kind of metal being worked determines the character of the file to be used. For cast iron, which presents a clean surface free from scale and an undue amount of rust, a bastard file is generally used. Although this is a softer metal than steel, it presents a surface of porous glassy character which is very hard on the cutting surfaces of a file. Old files—ones whose cutting surfaces have already been dulled by long use—should be used in cast-iron work. On steels of all kinds a second-cut file is generally accepted as presenting the best surface. The superiority of the second cut over the bastard for steel work is due to the fact that the cutting surfaces are shorter, and when sufficient pressure is applied for the file to bite into the surface, there is less tendency for these surfaces to chip off than there is with a coarser file such as the bastard.

Aluminum, bronze, brass, bearing metals of all kinds, and kindred soft metals permit the use of flat files with coarse cutting edges.

Fig. 6. Correct Bench Filing Position

**Manipulation of Files.** In filing, the work is usually held rigid in a vise, although many jobs are done directly on the automobile itself. In bench work, the surface should be at about the height of the elbow, and in constructing benches and installing vises it is well to bear this in mind.

*Handles.* Although it might appear to be a trivial matter, one cannot be too particular as to the kind of a handle which is fitted to the file. Before buying your files, hold them in your hand, with the handle against the palm and the other hand holding the steel end of the file. Press the file vigorously against a surface and determine for yourself whether the handle fits the palm in such a way that several hours of work would not become painful. Also make sure that the axis of the handle is on a true parallel with the file.

*Position for Filing.* If one is to undertake a filing job which will require several hours of concentrated labor, it is well for him to learn that position which will give greatest accuracy and which, at the same time, will be the least tiring. The feet should be placed a foot apart and at right angles to the work bench, or nearly so, Fig. 6, the left foot being in line with the top of the vise and the right slightly ahead of the left. This position allows the body to follow the file accurately and eliminates that swinging sideways movement which is disastrous to accurate work.

*Holding the File.* Take hold of the handle of the file with the right hand as you would take hold of the steering wheel of the car, with the fingers underneath and the thumb lying across the top. When a big

Fig. 7. Position of the Hands for Bench Filing

file is used and the work is heavy, grasp the steel end of the file with the left hand by placing the top of the file into the palm and twining the fingers around the end, Fig. 7. If the work is delicate, it is only necessary to pinch the end of the file with the fingers of the left hand.

Remember that the first dozen strokes of a new file on a tough piece of steel frequently lessens its cutting value as much as an hour of steady cutting on a softer metal. Handle the file firmly and push it into the metal with an even steady stroke to avoid chipping the edges. When much metal is to be filed, the direction of stroke should be changed frequently, thus permitting more accurate work as well as allowing faster removing of metal. The file, when moved endwise, produces small grooves in the direction of the work; when the direc-

tion of the file is changed, it cuts into the top edges of the grooves with much the same effect as working against the grain in wood.

**Uses of Different Shapes of Files.** We have gone into the types of files to be used as to coarseness or fineness of the cutting surfaces. Now let us consider the shapes best suited to various kinds of work.

When one selects a file for a certain job, he must bear in mind the shape and the size of the work, the quality of the metal, the amount of stock to be removed, and the quality of the finished work. The first two mentioned requirements fall under the shape of the file, the others under the nature of the cutting surfaces.

If the surface is a flat one, the flat file, hand file, or warding file will serve. The length will, of course, depend on the length of the surface to be filed. For very light work the length of the file should be about 8 inches, and for heavy work about 18 inches. If the surface is a square interior, such as a keyway, the square file finds its place.

The triangular file finds its use in notching round bars, in cutting through steel tubing, and in filing gear teeth, bolt threads, and kindred applications. The half-round file is used where the curvature of a radial filing job becomes too great for efficient work with a round file. With these large surfaces, it is not possible or even desirable to have the file fit accurately the surface to be cut. In using this file it is imperative, if smooth work is to be done, that the file be given a side sweep with each stroke. The round file, which in its general form is tapered throughout its length, has obvious uses in working with round holes.

**Accurate Filing.** The matter of accurate filing is a knack which can be acquired only by practice. It is the process of learning a smooth even stroke in which the file is held flat against the work throughout the length of the stroke. However, the file maker has contributed towards accurate work in a safe-edge instrument which has innumerable applications around a motor car.

*Use of Safe Edges.* Suppose one desired to increase the depth of a keyseat without in any way impairing the surfaces on the sides of that keyseat. If he were to introduce a flat file with cutting edges on all four surfaces, he would have removed considerable metal constituting the sides of the keyseat before he had cut the keyseat much deeper. For this kind of work there is the safe-edge file—one in which there are cutting surfaces on two opposing sides and smooth surfaces on the other two. These are procurable in all sizes and shapes.

*Draw Filing.* The term draw-filing refers to the process of operating the file over the work at right angles to the length of file. To do this work properly, the file is grasped in the palms of both hands, as one would grasp the handles of a push cart, Fig. 8. The purpose of this method of filing is accuracy in the work. As the belly of the file can be brought to bear on the high spots under better control and with less oscillation than in cross-filing, a less skilled mechanic can obtain more accurate results. Of course, due to the fact that the cutting surfaces operate on a great angle, the amount of cut at each draw is far less than it is in cross-filing.

*Filing to a Micrometer Fit.* Suppose one has a square block of steel, one side of which is to be cut down to an accurate surface with $\frac{1}{16}$ inch of stock taken off. Calipers or micrometers should be set

Fig. 8. Position of the Hands for Draw Filing

about $\frac{19}{64}$ inch greater than the finish size of the block. The surface may now be cut down with a flat second-cut file until the piece will just pass within the calipers or micrometers. Now the micrometer or calipers should be set to the exact dimension of the finished piece, and draw filing should be resorted to so as to cut down the surface carefully until the caliper or micrometer is a very tight fit over all the edges and through the center.

Now one should use a small file of a smooth fine grade for the final dressing off and should resort to the cross-filing method, so as to remove the grooves caused by the draw-filing operation. With a little filing, then a measurement from the caliper or micrometer, a little

more filing, and still another measurement, etc., a very accurate job is possible.

*Revolving Filing.* Quite another angle is presented in revolving filing. This means the filing of a piece of work which is revolving in a lathe chuck. The stroke for this kind of work is entirely different than in hand filing. These strokes are fewer and of longer duration inasmuch as the work is revolving rapidly and permits of faster cutting. In filing rotating work very nearly all of the cutting edges should be brought into play, that is, one should stroke slowly from one end of the file to the other.

The file should be held in the hands in the same manner as for cross-filing in a vise, as previously described. If the amount of metal to be removed is considerable, the file should be held at an angle, and, if it has single cutting edges, at the angle which presents these edges, flat against the work. The file should be turned over frequently and held at the opposite angle, thus cutting crosswise of the grooves caused by the cutting edges of the file.

If a smooth finish is required and the amount of surface to be removed is nominal, the file should be held at right angles with the work and turned over frequently. It should be swept in even movement from the right to the left of the surface being filed.

It must be remembered that less pressure is required to make the file bite in revolving work than in stationary work. This permits the use of special files for rotating work with concave surfaces which would not suit at all for stationary work. If one does not desire to purchase special machine files, there is an opportunity for using up the old stock which have become so warped and worn that they are no longer suitable for accurate bench work. This applies to the cutting of the radial surface of rotating work. If one is to file a flat rotating surface, such as the end of a disc, one must use an accurate file with a convex surface, the same as for bench work.

**Cleaning Files.** It is quite important, if one hopes to minimize the purchase of new files, that the ones in use be carefully cleaned after each operation. If the particles of metal removed in the cutting operation become packed into the teeth, this greatly diminishes the cutting powers of the tool. This cleaning may be done to some extent by striking the edge of the file against a solid surface, but such a cure is not a good one. The work can be done more effectively by using

a wire brush made for the purpose or by scraping the edge between the cutting surfaces with a thin piece of brass.

**Presence of Grease.** In filing any metal on the bench, it is well to assure yourself that all grease is removed both from the file and from the work. Grease tends to hinder the file from cutting into the metal. In steel work, where the job is revolving, the file may be frequently oiled, as this measure tends to keep the file clean.

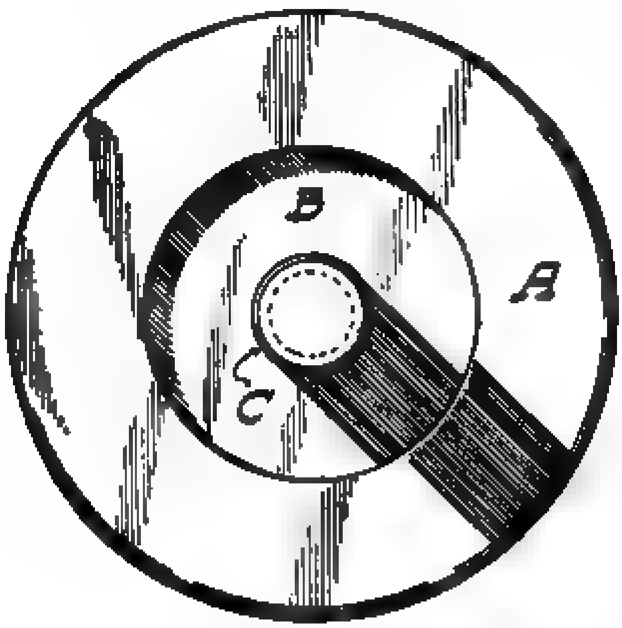



Fig. 9. Jig for Rebabbitting Bearings

When one is obliged to file objects in inaccessible places about an automobile, there is no rule which can be laid down other than to do the filing in the easiest possible manner. The work required is seldom so extensive that the file will be harmed, no matter how carelessly the work is done.

## REBABBITTING BEARINGS

**Types of Jig to Use.** There are still a few cars running which embody the old principle of solid bearings in which the bearing metal must be poured into the bearing container. This process is known as rebabbitting bearings. It is not good practice to use the main shaft for the purpose of casting the bearings, because the hot metal is apt to spring the shaft. A better plan is to use a wood jig such as shown in Fig. 9.

It is unfortunate but true that a new jig will probably have to be made for every different size of job, but the jig is easily turned in a lathe in one set-up of the chuck. The solid flange *A* should be about 1 inch thick and should have a diameter 1 inch or so greater than the outer diameter of the bearing. The shaft *C* should be turned to a size $\frac{1}{64}$ inch smaller than the size of the bearing surface, and should be about $\frac{1}{8}$ inch longer than the length of the bearing itself. Then on the

shaft side of the flange *A* should be turned a groove *B* having a depth of $\frac{1}{4}$ inch and a diameter equal to the diameter of the hole through the connecting rod when the babbitt metal is removed.

**Pouring the Babbitt.** The jig is now ready for use. Fill the groove *B* with plastic fire clay even with the surface of the flange and place the bearing container over the shaft of the jig, as shown in Fig. 10. The bearing container should be adjusted over the shaft of the jig so that the space on all sides is exactly the same, determining this with a tapered steel gage, Fig. 11. Drop the gage into one side and note the mark on the taper where it comes to rest when touching the jig shaft and the bearing container. Then move the gage about and determine whether the other side is too close or too far away. Continue this operation until the space to be filled is the same on all sides. It is important that the machined surface of the bearing container rests perfectly flat on the block.

Fig. 10. Jig and Bearing Container Ready for Pouring

With everything properly located, lay a rim of fire clay about $\frac{1}{4}$ inch thick around the top of the bearing container, as shown in Fig. 5, so that the space between can be filled with bearing metal above the edge of the container to take care of contraction.

Everything is now ready for the pouring of the bearing metal, which has been melted in a ladle. Before starting to pour, make sure

Fig. 11. Tapered Steel Gage

that all impurities which have risen to the top are skimmed off. These impurities, if allowed to pass into the bearing, might cause trouble later. Pour the metal from the ladle into the hole quickly and with a circular movement about the rim of the hole. It is important that it be poured in quickly, because babbitt cools very rapidly. However,

this does not imply that the metal should be splashed in recklessly with the probability of throwing out the setting of the jig.

**Finishing the Bearing.** Allow the metal to cool for a period of 30 minutes and then remove the jig by pulling it out of the hole with a screwing motion. If care has been taken in placing the clay, the babbitt bearing will be held firmly in the bearing container. If the bearing is too tight for the crankshaft, it may be scraped to a proper fit as described in the next section.

When babbitt bronzes are to be relined, it is also necessary that there be a core to fit within the bronze, this core to be the size of the piece upon which the bearing operates.

Of course it is necessary, after the pouring has been done, to chip off the excess babbitt on the upper and lower surfaces of the bearing, smoothing down these edges after the bigger portion has been chiseled off by the use of a coarse file. The final polishing may be done with a fine file.

## BEARING SCRAPING

To the amateur repair man, scraping bearings looks like a tremendous task. But if the proper facilities are at hand, it is a comparatively easy matter for a man with some shop experience.

**Dismounting the Motor.** In order to properly scrape both the connecting rod and the crankshaft bearings, the crankshaft must be removed. There is a method of scraping the crankshaft, or main, bearings without removing the crankshaft, but this operation is too difficult for the average repair man. The first step, of course, is to get the crankshaft out of the motor. This is done by first removing the motor from the frame, after it has been drained of all oil and water, and setting it on a motor stand, or on the bench if a stand is not available. The flywheel is now taken off, and then the cylinders. All that remains on the bench or stand is part of the crankcase with the crankshaft, connecting rods, and pistons. In most cases the removal of the pistons is necessary. By dropping the lower half of the crankcase, the crankshaft and connecting rods may be removed. This assembly should be placed on the bench and the connecting rods removed. Of course if the rods may be removed while in the motor, as is sometimes the case, it is advisable to do so.

**Holding Crankshaft.** A means of holding the shaft upright on the bench must be devised. Usually on the end of the shaft, there is

a flange with a number of holes drilled through. Place the flange end of the shaft on the bench, as shown in Fig. 12, and mark on the bench with chalk the places under the holes. Drill holes through the bench where the chalk marks appear, and bolt the shaft to the bench, using as many bolts as you have holes. The bolts should be long enough to run through the bench and have 1 inch left over.

**Cleaning and Fitting Connecting-Rod Bearings.** With the crankshaft in the position shown in Fig. 12, clean the shaft thoroughly with gasoline. Emery cloth should be used to rub down any cuts which appear.

*Cleaning Parts.* Immerse the connecting-rod parts in gasoline, and then rub them dry. The connecting rods, like the cylinders, are numbered from the front to the back of the motor, and in working with them, never put a rod in any but its proper position; that is, rod No. 1 should always be fitted to wrist No. 1. The connecting rods are now ready for an initial fitting.

*Putting Lampblack on the Crankshaft.* The connecting-rod wrists on the crankshaft having been cleaned and polished thoroughly with emery, the wrist corresponding to the rod to be fitted is blackened with lampblack. Let us say that rod No. 1 is to be fitted. A little lampblack mixed with oil is rubbed on the wrist with the finger. Connecting rod No. 1 is then placed in position and tightened. In doing this, care should be taken that the nuts are tightened as they should be. Many repair men make the mistake of assuming that the nuts may be drawn up in any order whatever. This is wrong. First tighten one nut a little, then the opposite one a little, then a third and the one opposite about the same amount. Now go back to the first and go over the nuts in the same order. This should be continued until all the nuts are tight and the bolts drawn up as much as possible without springing them. The bolts are very easily stretched and, therefore, care should be taken that they are not tightened excessively.

Fig. 12. Connecting Rod in Vertical Position for Adjusting Bearings

*Cutting-In Bearing.* When all the bolts have been drawn up. turn the rod around in one direction for awhile, then run it back and forth for a few minutes, and then all the way around again. The entire operation of cutting-in the bearing, as it is called, should last about 8 minutes. Then take off the connecting rod. The connecting-rod bearing will be covered with little black spots, caused by the lampblack being embedded in the soft metal of the bearing. A piece of clean emery cloth should be used to rub the surfaces of the bearing. The rubbing should be continued until the surfaces are as clean as possible.

*Filing Shims.* If no black spots appear it is evident that the bearing was not touching the crankshaft at any point. If it is noticed that the rod does not fit snugly when the initial fitting is given, then the shims should first be filed. These are the thin pieces of metal which rest between the two halves of the connecting-rod bearing and regulate the tightness of the bearing. A filing block of wood should be made as shown in Fig. 13. The block should be gouged on its surface in two places so that the resulting shapes resemble those of the shims. They need not fit perfectly, but the indentations must be of the same depth and still too deep to prevent filing the surface of the shim. The shims, when placed in these grooves, are ready for filing. Both shims should be filed at the same time. The block should be placed in the bench vise or in a metal vise. Then a fine mill file should be run over the surface of the shims by holding the file as previously instructed. Do not file much, the object of filing being to bring the two halves of the bearing halves closer together so as to touch the shaft. It will be seen from this that considerable accuracy is necessary in filing shims. The shims should be perfectly level.

Fig. 13. Shims Mounted for Filing

*Scraping Process.* With the shims filed, place them in position and give the bearing another fitting. Remember the filing was done to bring the bearing together. When it is properly closed, the rod should fit tight enough to require some effort to push it around. Taking for granted that the bearing has been given a fitting and that it has been found to contain a number of black spots, as shown in Fig. 14, the scraping will be begun. For this operation a bearing

scraper, Fig. 15, is used. This may be procured at any supply store. The scraper is held as shown in Fig. 14. However, one who is accustomed to scraping may be able to handle the instrument better in another position. One very important point must be borne in mind and that is that the word scraping does not mean — as it usually does—scratching; scratching is detrimental to the bearing. By scraping is meant cutting from the surface of the bearing a very thin shaving of metal and at the same time leaving the surface of the bearing smooth.

Fig. 14. Inside of Bearing Showing Spots Which Need Scraping

The real object of scraping is to get the bearing to touch the crankshaft at every point. A bearing may be said to be a good one if every $\frac{1}{32}$ inch of the surface touches the crankshaft. It will be supposed that the bearing needs scraping. It does not show little black spots every $\frac{1}{32}$ inch. Instead there are groups of spots, at each end as at *a* and *b*, Fig. 14, while in the center portion *c* there are no spots, which means that at this point the bearing is not touching the shaft at all. The object of the scraping is to make the center portion as well as the two ends touch.

The little black spots are scraped off one at a time or nearly so, using short clean strokes with the scraper and taking care not to roughen the surface of the bearing. The scraper should be moved

Fig. 15. Type of Bearing Scraper

sideways and at the same time a little forward. One hand is necessary to manipulate the scraper and the other to guide the tool.

After all the black spots have been removed, the bearing is thoroughly cleaned with a cloth. The wrist of the crankshaft is again blackened with lampblack and the rod given another fitting. If at

this fitting the rod is loose, due to the bearing having been scraped too much, the shims should be filed a little. After the rod has been turned on the crankshaft for about 5 minutes, it should be removed and the bearing again examined.

Little black spots will again be seen, but this time they will be more evenly distributed if the bearing was properly scraped before. If the entire surface of the bearing contains black spots about $\frac{1}{32}$ inch apart, then the bearing is in good condition. But this holds true only if the rod holds snugly on the shaft. If the black spots are again grouped as shown at *a*, *b*, and *c*, then the individual spot scraping is repeated until the rod gives a snug fit and at the same time has the bearing touching uniformly.

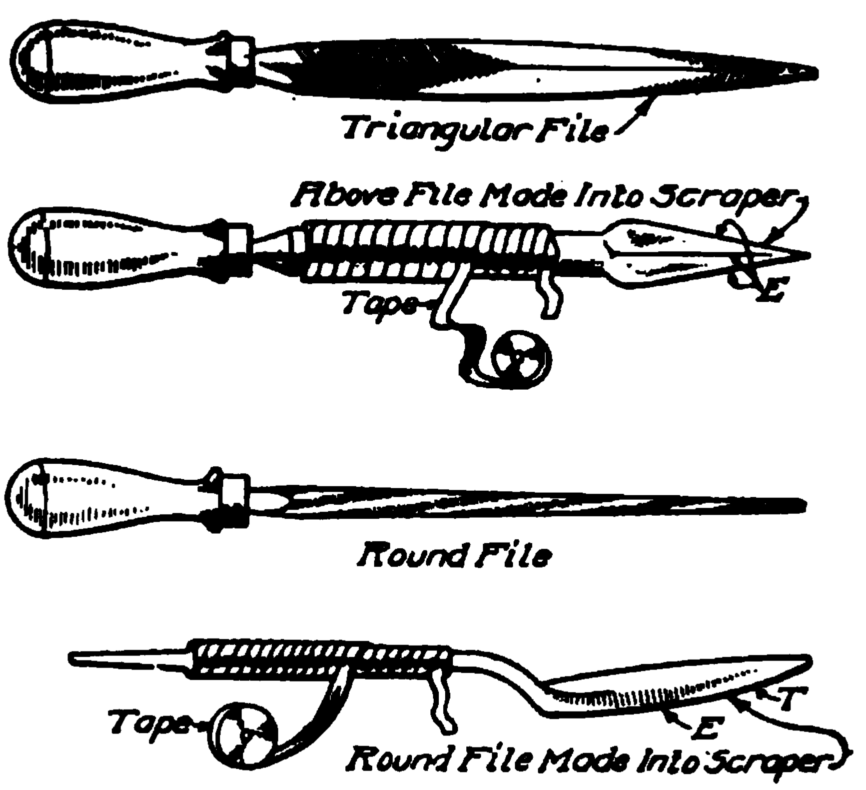


Fig. 16. Scrapers Made from Old Files

**Bearing Scrapers from Old Files.** Old files, when properly worked into shape and tempered, make excellent bearing scrapers. There are several advantages in favor of the use of a homemade scraper; first of all it is possible to make a scraper that will be more adaptable to the hands of the workman than the standard type.

In Fig. 16 is shown some of the types of scrapers best made from old files. The way to go about making a scraper is to select an old file resembling the type of scraper desired. Heat the file to a light-red heat and forge with a hammer, or bend in a vise as required.

When this is done, allow the file to cool slowly in the ashes at the side of the forge. When cool, it will be much softer than in its original state and most probably will be soft enough to be filed readily into the exact shape desired. If too hard to file conveniently, an emery wheel may be brought into service to shape the tool.

When the proper shape has been obtained, the next operation is to temper the tool. This is done by heating it again to a light red, then immersing the scraper portion in cold water and moving it about for a few seconds until it has entirely lost its red color. It should now be withdrawn and its bright surfaces quickly sandpapered so that the

changes of color can be noticed; then when a light yellow or straw color appears, the whole tool should be immersed in water, moved about therein for a few minutes, and then left there until cold.

The last step in the manufacture of the homemade scraper is to grind the surfaces of the tool so as to get smooth sharp-cutting edges. The sharp-edge scraper will of course have its three cutting edges formed by hollow-grinding the surfaces so that about $\frac{1}{16}$ inch of the original flat surface remains on either side of the edge. These surfaces remain flat and afterward are smoothed up on an oil stone.

## SOLDERING

**General Instructions.** It is quite necessary to make use of solder on various parts of the automobile, such as the radiator, the tanks, and the lamps, in spite of the fact that when subjected to stress or vibration such procedure is not considered best. Certain principles must be kept in mind if permanent work is to be accomplished. Cleanliness is a watchword; the surfaces to be joined must be clean, and this cannot be carried too far. Chemically, the metal must be clean as well as free from any oxide. The use of sandpaper or a file to clean and brighten the surfaces is recommended, and this work should be done immediately before the soldering process is begun. It is well to bear in mind that the surfaces of the metal as well as the solder must be hot if a permanent job is to be done. The solder must flow freely, otherwise it will not enter the pores of the metals. Always keep the soldering iron well tinned. Never let it get red hot.

**Soldering Flux.** The ordinary flux is made by placing zinc clippings in strong hydrochloric acid until no more will dissolve. Some special preparations which are noncorrosive give very good results in soldering. Work soldered with the zinc-hydrochloride as a flux should be thoroughly washed afterwards. A list of the more usual fluxes for the different metals is as follows:

FLUXES FOR SOLDERING

| | |
|---|---|
| Iron or steel | Borax or sal ammoniac |
| Tinner iron | Resin or chloride of zinc |
| Copper to iron | Resin |
| Iron to zinc | Chloride of zinc |
| Galvanized iron | Mutton tallow or resin |
| Copper or brass | Sal ammoniac or chloride of zinc |
| Lead | Mutton tallow |

**Light Work.** Light work in wire, sheet, and tubes of copper, brass, or iron can be soldered with an ordinary soldering iron, or in a Bunsen flame. The essentials are thorough cleanliness from grease and oxide of the parts and the iron itself, a suitable flux, a good quality of solder, and the iron brought to the right temperature.

**Heavy Work.** To solder a large tank or radiator, the water should be run out, the place to be soldered should be well prepared, and a large copper soldering iron—sometimes called a "bit"—should be used, preferably one which is automatically heated by a blow lamp. Such a repair is not easy to make, owing to the large cooling surface of the metal. The tank or radiator may have to be taken off the car in order to make the repair conveniently. A soldered joint, of course, will not resist much strain or vibration, and in some cases it is advisable to reinforce the repair by riveting. A brazed joint is much stronger, but brazing is a much more difficult process and should be done only by a skilled operator.

Fig. 17. Soldering Iron Heating Stove
*Courtesy of Central Electric Company, Chicago, Illinois*

**Position of Work.** Soldering requires time and judgment. Sufficient time must be given for the heat to flow from the copper to the work. Seams should be held horizontally to prevent the solder

Fig. 18. Electric Soldering Iron
*Courtesy of Central Electric Company, Chicago, Illinois*

from running away from the seam. The area of the joint being soldered must be large, as the elastic limit of solder is much below its tensile strength. Be sure that the soldered joint is not subjected to bending or other stresses that will localize the strain on the solder.

**Use of Blow Torch.** If two pieces of considerable thickness are to be soldered, the work cannot be done successfully with a soldering iron, as the metal absorbs the heat faster than the iron can supply it;

consequently, repairs of this kind are usually accomplished by the use of a blow torch. First the ends of the two pieces to be soldered are tinned—covered with solder separately. Then the two surfaces are put together and the blow torch applied, melting the solder and forming a perfect union. Another method sometimes used is known as sweating, in which the two pieces of metal to be joined are first heated by a blow torch in order that the heat from the actual process of soldering will not be so largely consumed by the metal itself. The more tin there is in solder the stronger it is, but it is harder to melt than that in which lead is the predominating element.

**Special Stoves and Irons.** Special stoves for heating soldering irons are made and vary in construction. Fig. 17 shows one of the most common forms of soldering-iron heating stoves. Some shops make use of an electric iron for soldering, wherein the temperature of the iron is uniform. Such a tool is shown in Fig. 18.

## FITTING PISTON RINGS

**Importance of Piston Rings.** Notwithstanding the fact that the fitting of piston rings requires much accuracy, the average repair man is satisfied if the rings merely fit into the guides in the piston. If every repair man would only stop and think, he would realize that a great deal depends upon the condition of the piston rings and that considerable care should be exercised in fitting them to the piston.

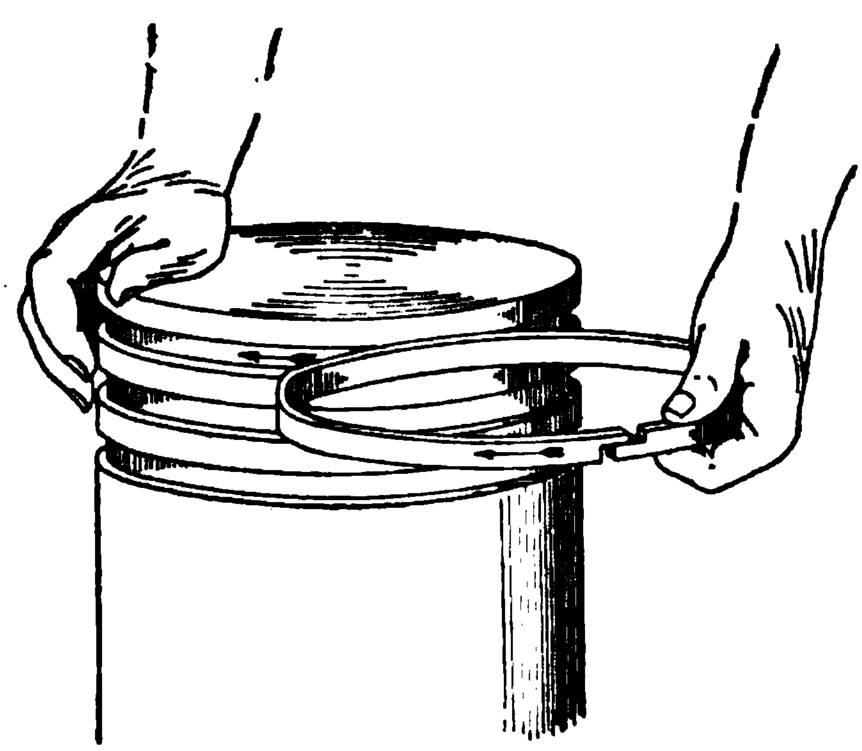


Fig. 19. Starting Piston Ring in Groove to Test the Fit

**Fitting Ring in Groove.** The first move in fitting rings is to get the grooves or guides of the piston thoroughly clean. This should be done by immersing the piston in gasoline and spraying it thoroughly to remove the least particle of dirt. Much time may be saved by trying the rings in the various grooves to see which ring most nearly fits a given groove.

In Fig. 19 is shown how the ring should be started in the groove, and the arrows show the direction in which the ring should be moved.

The entire circumference of the ring should be rolled around the groove. Of course, if the ring will not fit into the groove, try another groove. The reason the back end of the ring is fitted first instead of the inner is because the latter fitting would require that the ring be put in its usual position around the piston. Slipping the rings over the piston head is not easy in itself and would be difficult were the rings not of the proper size.

**Testing and Correcting Length of Ring.** The ring should next be inserted into the cylinder to determine whether the ends are the proper distance apart. The distance between the ring ends, when the ring is in the cylinder, varies with the different designs. An electric lamp dropped into the cylinder, while the ring is in, will show immediately whether the ends of the ring are touching. If they do touch, they should be filed slightly, as shown in Fig. 20. The ring should be placed in a vise with one end protruding about an inch. A little of the ring is left sticking out so that it will not sway when filing is being done. The file—a very fine mill file—is placed between the ends as the sketch shows, with the left hand pressing the long end of the ring lightly against the file. The operation should continue for a short time only, about twelve strokes of the file being sufficient. The ring should be put back in the cylinder and the distance between the ends measured with a thickness gage, or as it is called by factory men, a feeler. Fifteen-thousandths is a good distance to allow if the factory measurements cannot be obtained.

Fig. 20. Filing Piston Ring to Give Proper Spacing

**Lapping In the Ring.** The next step is to make the ring fit its groove properly. Lapping is the term applied to the operation of grinding the ring down so that it fits. A level steel surface is used, upon which is sprinkled enough very fine emery dust to cover it. Enough water is added to make a pasty mass. The ring is then

placed on the steel plate and a block of wood about 6 by 6 inches placed on top of the ring; by exerting a slight pressure on the block and applying a rotary motion, the ring is moved about over the emery.

If the ring will not stay under the wood block, cut a little notch in the block to hold the ring still. After grinding for a few strokes on one side, the ring should be turned over and an equal amount of grinding done on the other side. The entire operation should not last longer than one or two minutes. After lapping, the ring should be immersed in clean gasoline and fitted to the groove which it most nearly fitted before. If every part of the circumference of the ring fits every part of the groove, then the lapping is complete and the ring may be tagged to designate its location. The figures 1-1 on a tag usually represents the first cylinder ring No. 1, this ring being the one nearest the top of the piston. If one part of the ring fits and another does not, the place that is too tight will show up when the ring is dipped in gasoline and then rubbed with a cloth. The high spot will be more shiny than the rest. Lay the ring perfectly flat and with a fine file take a little off from both sides of the ring. Only a little should be taken off at a time, and the ring should be tried after each filing.

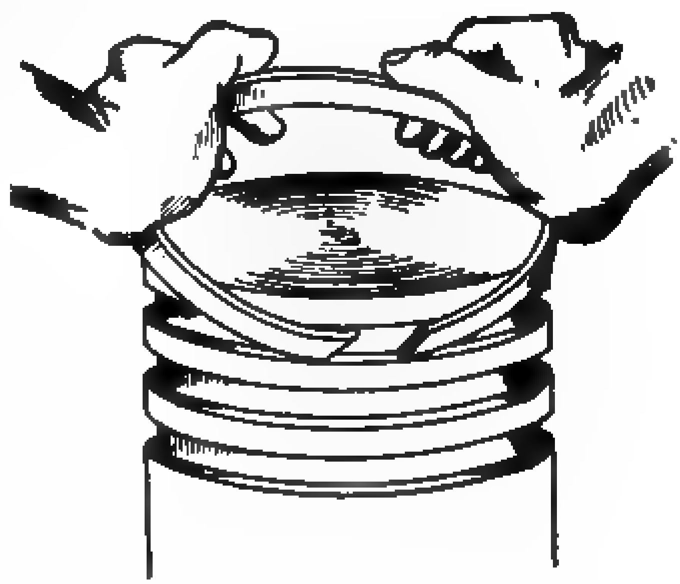


Fig. 21. Putting Piston Ring on Piston End

Fig. 22. Using Metal Strips in Properly Placing Piston Rings

**Replacing the Rings.** When all the rings have been filed in this way, the next step is to place them in their respective grooves, making them occupy their proper position when in use. In Fig. 21 is shown a method for doing this. Ring No. 4 should first be placed in position.

For this operation, three pieces of saw blade with the teeth ground off are used. Hold one blade against the piston with the left hand and with the right hand bring one end of the ring in contact with the blade. Get the blade about $\frac{1}{2}$ inch from the end of the ring, so that the blade can be held in place by pressure against the ring. Then slip the ring over the piston top. There is a space on either side of the blade through which the other blades may be inserted. Push the blades around until they appear as shown in Fig. 22. By sliding the ring on the three blades, it may be placed easily in its groove. With the lapped ring in its groove, the ring must fit so that it may be turned around easily. No up and down play must exist.

**Miscellaneous Adjustments of Rings.** There are several things to be looked for to determine whether the piston rings are functioning as they should. If gas has been working its way past the rings or if the rings have not been fitting the cylinder walls properly, points where the gas passed will be evidenced by burned, browned, or roughened portions of the polished surface of the piston and rings. Points where this discoloration is noted will more often be at the thin end of an eccentric ring, the discoloration being apparent about $\frac{1}{2}$ to $\frac{3}{4}$ inch each side of the slot. Possibly the rings were not true when put in.

It is well to bear in mind that before replacing pistons in the cylinders one should make sure that the slots in the piston rings are spaced equidistant on the piston. If pins are used to keep the rings from turning, one should be careful to make sure that these pins fit into their holes in the rings and that they are not under the rings at any point. Putting pistons in cylinders really requires the use of two pairs of hands. The manipulation of pistons is discussed in Gasoline Automobiles, Part I.

**Fitting New Rings.** Fitting new rings will not prove of advantage unless the cylinders are in good condition. Before making a new ring installation, make sure that the cylinders are not out of round, warped, or scored. If found to be so, they should be reground and oversize pistons and piston rings installed. Piston rings must have a uniform wall pressure of sufficient strength to maintain a bearing against the cylinder walls during every revolution of the engine. Piston rings that will assume the shape of the worn or warped cylinder do not have the necessary wall pressure and will collapse under the force of expansion.

## USE OF MICROMETERS

**Principle of Operation.** In case measurements are required to be more accurate than can be obtained with the ordinary calipering devices, the micrometer caliper, as shown in Fig. 23. is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

Essentially, the micrometer caliper consists of a crescent-shaped frame carrying a hardened steel anvil *B* at one end and a nut of fine pitch at the other, the axis of the nut being at right angles to the face

Fig. 23. Transparent View of Micrometer Caliper with Friction Stop
*Courtesy of L. S. Starrett Company, Athol, Massachusetts*

of the anvil. The outside of the nut *A* forms a projection beyond the crescent that is called the barrel. The measuring screw consists of a finely pitched screw to fit the nut, combined with a measuring point *C*, having a face parallel with that of the anvil. To the outer end of this screw is firmly attached a thimble *D*, which fits closely over the barrel. The edge of this thimble is beveled at *A* so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel, parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel of the instrument indicates a movement of the measuring point of .001 inch. To illustrate: if the pitch of the measuring screw is .01 inch, there should be ten divisions on the thimble; if .02

inch, twenty divisions; if .04 inch, forty divisions. Most measuring screws have a pitch of .025 inch and these are the type usually used, every fourth dimension on the barrel being lengthened and numbered to indicate tenths of an inch.

**How to Use Micrometer.** When using the micrometer caliper, it should not be set to the size desired and pushed over the work, but should first be opened, then screwed down until the measuring point *C* and the anvil *B* are in contact with the work. The size may then be read by taking the number of scale divisions on the barrel and adding the value of the parts on the thimble corresponding to the reference

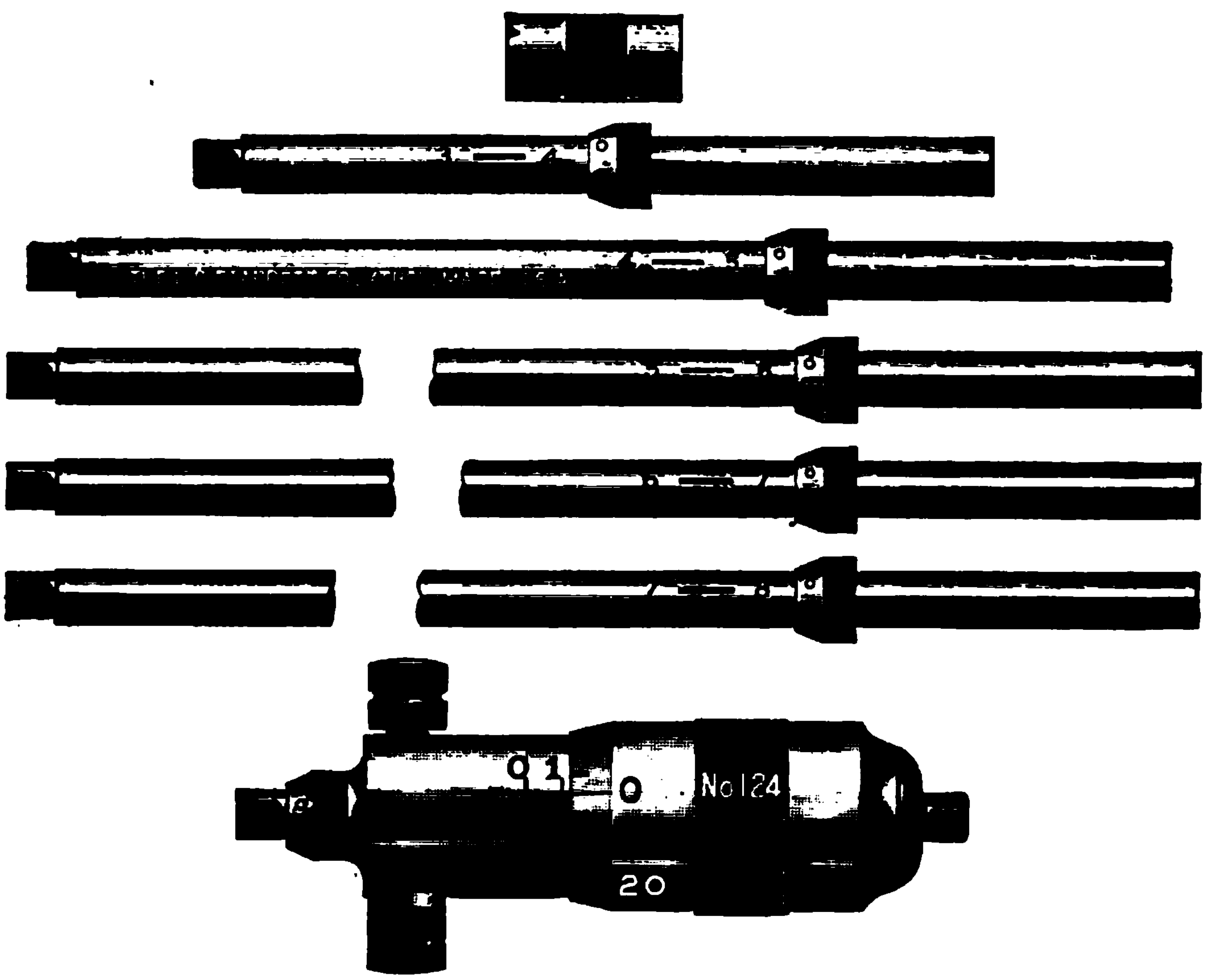



Fig. 24. Inside Micrometers
*Courtesy of L. S. Starrett Company, Athol, Massachusetts*

line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble, as shown at the extreme right of Fig. 23, so that undue pressure cannot be exerted.

**Value of Micrometer.** The value of the micrometer caliper cannot be impressed too strongly upon the user. Not only does it show when work is too large or too small, but it gives the exact amount of variance in desired measurements. It is a distinct improvement over the caliper and enables the user to work with accuracy. The 1-inch size is the most common, but micrometers may be obtained in all sizes

up to 20 inches. Using the micrometer for inside measurements is not the usual application, but it is easy to arrange and makes a very simple instrument, as shown in Fig. 24. The ordinary micrometer head is used, except that the outer end of the thimble carries a contact point, attached to a measuring rod which may be of any length. The shortest distance that can be measured with this device is about 2 inches, but there is hardly any limit to length, since the rigidity of the rod is easily accounted for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement, which fixes the outside limit of this form to about 20 inches.

**Reading the Micrometer.** All readings are in thousandths. The usual micrometer has forty threads to the inch and the thimble has twenty-five divisions on its circumference. The barrel is divided to correspond to the pitch of the screw with each fourth division numbered. In reading, first note the highest numeral visible on the barrel and express it as so many hundred thousandths; then read the short divisions on the barrel, calling the first division twenty-five thousandths, or .025; the second, fifty thousandths, or .050; and the third, seventy-five thousandths, or .075. Now read the number indicated on the thimble, that is, the number that has passed the line running lengthwise. Add this reading to the readings of the short divisions. The result of adding the highest numeral visible on the barrel, which is expressed in hundred thousandths, the short divisions on the barrel and the number indicated on the thimble, give the distance from the anvil to the measuring point. If the micrometer caliper is a good one, we may be sure the distance does not exceed or fall short of the figures given by .001 inch.

## LAPPING CYLINDERS

**Worn Cylinders.** Where a cylinder of an automobile engine has become worn slightly out of shape or where the rings do not bear equally on the surface of the cylinder wall, the defect may be remedied entirely or to a great extent, depending on the magnitude of the defect, by lapping the cylinder wall. This measure will not cure the cylinder which has become scored but applies only to one which has been worn a very few thousandths of an inch out of round.

**Lapping by Hand.** The job can be done satisfactorily only by using an old piston of the same bore as the cylinder which is being

worked upon. If one does not have a drill press, the hand operation, which will give a very satisfactory job, should be done as follows: Support the cylinder in its inverted position on the work bench. Inasmuch as practically all motors of present-day construction are of the block cast type, this heavy casting should be well supported in an upright position in order that the lapping may be done conveniently.

*Cleating Down the Casting.* Probably the best and easiest way to support the casting is by cleating it to the bench, as shown in Fig. 25. If the motor is a four- or six-cylinder block-cast type, use three sets of cleats on each side. These consist of a block of wood laid against the side of the cylinder block and clamped in place by wood pieces mitered off at a 45-degree angle, the mitered edge of one end nailed to the block and the mitered edge of the other end nailed to the work bench. This cleating will support the block substantially.

Fig. 25. Cleating Casting to Bench

*Proper Fit for Piston.* Before proceeding with the work, one must determine that the old piston which is to be used is a proper fit in the cylinder to be lapped. It must be such a tight fit as to require considerable pressure to move it up and down. On the other hand, a loose fit will mean uneven grinding and a great deal more work to obtain the proper lapped surface.

The piston should have a connecting rod fitted into it, or better still, a rod of such a length that it will protrude about 18 inches above the top of the piston. If one contemplates an extensive business in cylinder lapping by the hand method, it would be well to fit up a number of standard size pistons with rods such as just described. The connecting rod itself, however, will serve the purpose if the jobs are so few that they do not merit the special tools.

**Emery Paste.** With the cylinders blocked up on the work bench and a suitable piston at hand, one is ready for the lapping operation. There are several pastes on the market made up of fine emery and an oil body which are excellent for lapping work. However, one can make the necessary material himself with very fine emery dust, ordinary motor oil, and a bit of graphite worked into the paste. This compound should be made up to the consistency of library paste and applied thoroughly to the walls of the cylinder to be lapped and to the surface of the piston to be used for the lapping.

When applying the paste, watch the surface upon which it is being applied with great care, especially if the paste has been made up previously and allowed to stand around the shop for some time. It is very easy for metal chips and filings to be dropped into the paste, and if these get into the cylinders when the lapping operation is under way, they are liable to scratch, or score, the surface.

*Grinding Process.* Lower the piston into the cylinder and proceed with the lapping. In performing this, lower and raise the piston, at the same time maintaining a circular motion, thus turning the piston around so that all surfaces of the piston will be brought to bear upon all parts of the cylinder.

Fig. 26. Cylinder Mounted on Drill Press Bed for Lapping Job

This operation should be continued for a period of from 15 to 30 minutes, depending upon the condition of the cylinder interior. It will not remove scratches and scores and will not iron out a warped or egg-shaped cylinder, but it will dress down the small humps and impart a very smooth glass-like finish to the cylinder walls.

**Lapping by Drill Press.** If the repair shop is equipped with a fair size drill press, lapping can be performed quickly on this machine. It is especially easy when one has to deal with separate cast cylinders

inasmuch as these can be clamped into the drill-press bed without need of special supports, Fig. 26. However, if the job is a block-cylinder casting, one must provide some means of support outside of the drill-press bed and inasmuch as it is a matter of blocking from the floor, it is for the ingenuity of the repair man to devise the best method.

*Piston Rod.* In drill-press lapping of cylinders it is, of course, necessary that a rod be used to take the place of the connecting rod, this rod to fasten to the wrist pin at one end and be so shaped as to lock into the chuck of the drill press at the other end.

It is well to cut a block of wood which when dropped into the inverted cylinder will come up to the line which marks the top of the piston stroke. To lap the cylinder, the old piston is coated with the lapping paste as previously described and let down into the cylinder. The drill press must be turned at its lowest possible speed. When the lapping is going on, the drill-press arm should be let up and down so that the position of the piston is constantly changing within the cylinder. Of course lapping by this method can be accomplished in about half the time required by the hand method.

**Cleaning after Grinding.** At the completion of hand or machine lapping, the cylinder interior should be thoroughly washed out with gasoline and the surface polished with a soft cloth. It is imperative that all emery be removed from the cylinder as it would undoubtedly injure the bearings or some other part of the motor, after the motor has been assembled and run.

## DRILLING

**Types of Drills.** There are two kinds of drills which are found in modern repair shops, the *twist* drill and the *flat* drill. The former is the one which is used in practically every kind of work, although the flat drill has as its function the performance of certain operations which the twist drill will not handle at all.

*Flat Drills.* The flat drill, Fig. 27, is the simplest and, incidentally, the oldest type; until the invention of the twist drill, the flat drill was used for all drilling work. It is made from a piece of round stock, on the end of which are forged thin lips which are ground with three cutting edges, the edges being on the V-shaped end of the tool. For the performance of accurate work the flat drill is a poor tool, its field being in rough drilling of extremely hard metals. As a deep hole drill it is useless because it does not free itself of chips. For

drilling out a cored hole in an iron or steel casting preparatory to boring, the flat drill is superior to the twist drill, inasmuch as this work is very injurious to the twist drill because of scale and sand which is bound to be within the core.

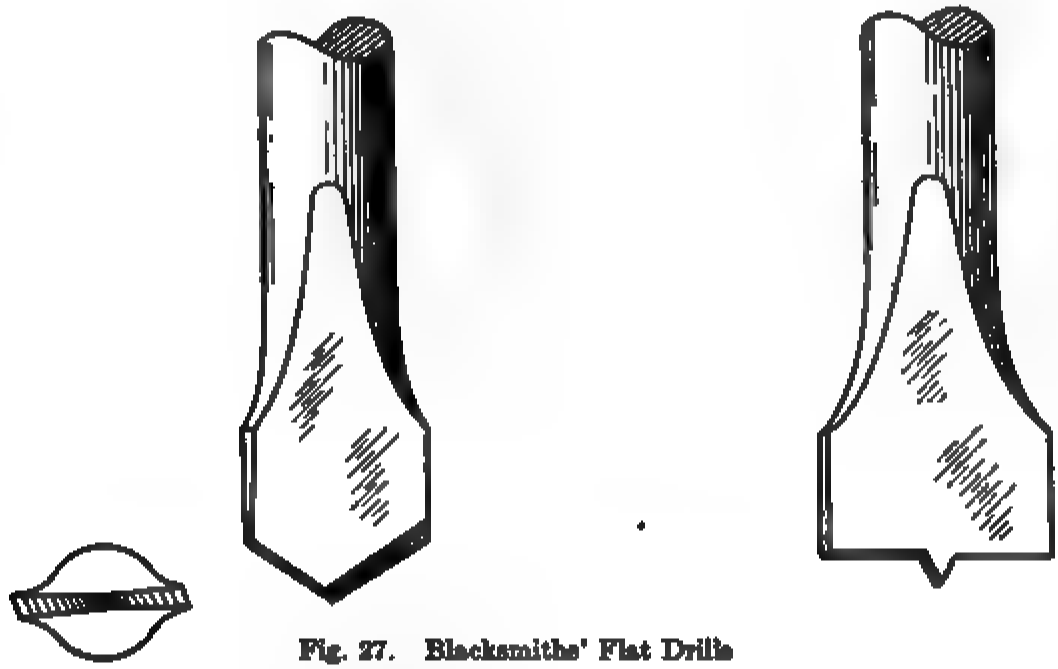


Fig. 27. Blacksmiths' Flat Drills

*Twist Drills.* In small drill sizes, the twist drills come in straight shanks, Fig. 28, while in the larger sizes, taper shanks, Fig. 29, are most generally used. The shank is the part of the drill which fits into the holding device whether it be the chuck of a drill press or a bit.

Fig. 28. Typical Twist Drill
*Courtesy of Union Twist Drill Company, Athol, Massachusetts*

As will be seen from the illustrations, a twist drill is fluted or grooved in spirals which follow the direction of rotation of the drill. These flutes serve to carry the chips from the cutting edges which, as is the case with the flat drill, are on the V-shaped end of the tool; the


Fig. 29. Taper Shank Twist Drill
*Courtesy of Morse Twist Drill Company, New Bedford, Massachusetts*

flutes also act as a channel through which lubricant may be directed to the cutting edges. For small drills the blanks are usually made from steel wire and for large drills from round steel stock. The flutes are milled into the tool.

**TABLE I**

**Morse Tapers**

| No. of Taper | Taper per Foot | Smallest Drill Using Each Taper (in.) | Largest Drill Using Each Taper (in.) |
|---|---|---|---|
| 1 | .605 | [illegible] | $\frac{9}{16}$ |
| 2 | [illegible] | $\frac{37}{64}$ | $\frac{29}{32}$ |
| 3 | [illegible] | $\frac{59}{64}$ | $1\frac{1}{4}$ |
| 4 | .615 | $1\frac{17}{64}$ | 2 |
| 5 | .625 | $2\frac{1}{32}$ | 3 |
| 6 | .634 | Special | Special |

**Grinding Drills.** Great care must be exercised in grinding the twist drill. The angle of lip clearance—the lips being the cutting edges—should be greater at the center than at the outside of the lips. This is to permit the part of the drill which first touches the metal to be drilled to bite in. The usually accepted angle is about 12 degrees, as shown in Fig. 30. If the difference in the angle on the lips is too great, the drill bites too quickly, which may result in tearing off or chipping the cutting edges. If, on the other hand, the angle is too small, the cut is slow, and the drill will consequently heat excessively. Although there are a number of drill grinders on the market which do satisfactory work, the use of drills in a motor-car repair shop is seldom sufficient to warrant the purchase of one. After a little experience with drilling, one can determine the angles which give the best results by the "feel" of the drill and the dull drills can be ground accordingly.

Fig. 30. Cutting Edge Clearance

**Sizes of Drills.** The taper-shank drill is made in six sizes and the shank has the Morse taper. The exact taper and the limiting sizes for which each drill is generally used are given in Table I.

These taper-shank drills are carried as regular stock in all sizes by 64ths from $\frac{1}{8}$ to $2\frac{1}{2}$ inches and by 16ths from that size up to 3 inches. If one needs a drill larger than 3 inches, which would surely be a rare occasion in garage work, that drill would have to be made to order.

The wire gage sizes run by number rather than by dimensions, ranging from No. 80, the smallest twist drill made, up to No. 1.

## TABLE II

### S.A.E. Standard Taps and Drills

| Sizes of Taps | Sizes of Drills |
|---|---|
| 1/4 inch × 28 threads......... | 7/32 inch |
| 5/16 inch × 24 threads......... | 17/64 inch |
| 3/8 inch × 24 threads......... | 21/64 inch |
| 7/16 inch × 20 threads......... | 3/8 inch |
| 1/2 inch × 20 threads......... | 7/16 inch |
| 9/16 inch × 18 threads......... | 1/2 inch |
| 5/8 inch × 18 threads......... | 9/16 inch |
| 11/16 inch × 16 threads......... | 39/64 inch |
| 3/4 inch × 16 threads......... | 43/64 inch |
| 7/8 inch × 14 threads......... | 51/64 inch |
| 1 inch × 14 threads......... | 59/64 inch |
| 1 1/8 inch × 12 threads......... | 1 3/64 inch |
| 1 1/4 inch × 12 threads......... | 1 11/64 inch |
| 1 3/8 inch × 12 threads......... | 1 19/64 inch |
| 1 1/2 inch × 12 threads......... | 1 27/64 inch |

The above tap drills allow a thread within 1/64 inch of full thread.

**Speed of Drills.** The speed at which drills are driven has an important bearing on their wearing quality. Of course small drills can revolve faster than large drills. The proper feeds for drills—which means the speed of cutting as regards depth—varies with the kind of metals which are being cut. A very small drill can cut .02 inch per revolution in cast iron; a large one can cut no more than .005 inch.

**Lubrication.** For cutting malleable iron or steel the drill must be continually flooded with oil, while in cast-iron, aluminum, and brass drilling, the cutting is performed dry.

## TAPPING

**Standard Threads.** Tapping is that process of cutting on the walls of a drilled hole a series of threads into which a screw is to be

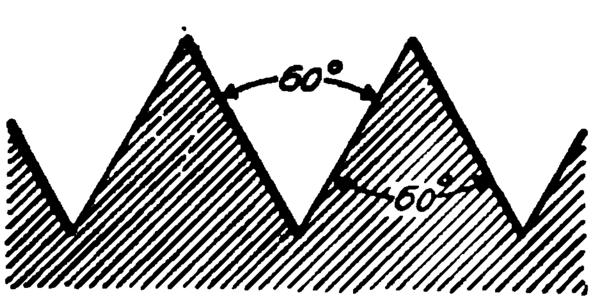



Fig. 31. Section of V-Thread

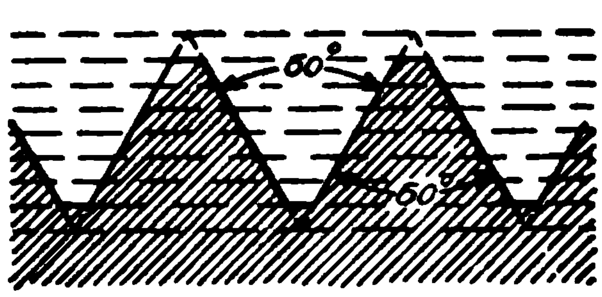



Fig. 32. Section of United States Standard Thread

fitted. In practically every instance in motor-car practice, the standard taps and drills specified by the Society of Automobile

### TABLE III
### Drill Sizes for Standard Threads

| Size Screw | No. of Threads | Size of Drill | | | Size Screw | No. of Threads | Size of Drill | | |
|---|---|---|---|---|---|---|---|---|---|
| | | U.S.S. | V | W | | | U.S.S. | V | W |
| 1/4 | 24 | .201 | .196 | .202 | 15/16 | 9 | .808 | .790 | .810 |
| 1/4 | 20 | .191 | .184 | .192 | 1 | 8 | .854 | .832 | .856 |
| 5/16 | 18 | .248 | .239 | .249 | 1 1/16 | 8 | .917 | .894 | .919 |
| 3/8 | 16 | .302 | .293 | .303 | 1 1/8 | 7 | .957 | .932 | .960 |
| 7/16 | 14 | .354 | .345 | .355 | 1 1/4 | 7 | 1.082 | 1.057 | 1.085 |
| 1/2 | 13 | .409 | .399 | .410 | 1 3/8 | 6 | 1.179 | 1.144 | 1.182 |
| 1/2 | 12 | .402 | .391 | .403 | 1 1/2 | 6 | 1.304 | 1.269 | 1.307 |
| 9/16 | 12 | .465 | .453 | .466 | 1 5/8 | 5 1/2 | 1.412 | 1.372 | 1.416 |
| 5/8 | 11 | .518 | .506 | .520 | 1 5/8 | 5 | 1.390 | 1.347 | 1.394 |
| 11/16 | 11 | .581 | .568 | .583 | 1 3/4 | 5 | 1.515 | 1.472 | 1.519 |
| 3/4 | 10 | .632 | .618 | .634 | 1 7/8 | 5 | 1.640 | 1.597 | 1.644 |
| 13/16 | 10 | .695 | .680 | .697 | 1 7/8 | 4 1/2 | 1.614 | 1.566 | 1.619 |
| 7/8 | 9 | .745 | .728 | .747 | 2 | 4 1/2 | 1.739 | 1.691 | 1.744 |

The above sizes give an allowance above the bottom of the thread on sizes 1/4 to 2, respectively, varying as follows: for V-threads, .010 inch to .055 inch; for U.S.S. and Whitworth threads, .005 to .027 inch.

These are found by adding to the size at the bottom of the thread one-quarter of the pitch for V-threads and one-eighth of the pitch for U.S.S. and Whitworth, the pitch being equal to 1 inch divided by the number of threads per inch.

In practice it is better to use a larger drill if the exact size called for cannot be had.

Engineers, Table II, will be used. Drill sizes of U.S.S., V-Standard, and Whitworth threads are given in Table III.

The V-thread is shown in Fig. 31. The U.S.S. thread, Fig. 32, is the same as the V-type except that the tops are cut off and the roots, or bottoms, of the threads are filled in. It is more cheaply produced than the V-thread and does not cut so deeply into the stock, leaving a stronger root. In the Whitworth, or English Standard threads, the tops of the threads are rounded off and the roots are concave. In the S.A.E. Standard thread the U.S.S. principle of construction is used.

**Taps.** The tools used to cut internal threads is known as a tap, external threads being cut with a die. There are hand taps and machine taps. The difference is principally in the shank. Hand taps have round shanks which are milled square on the end to receive the tap wrench. Three types of taps, called the taper, plug, and bottoming taps, Fig. 33, generally constitute a set.

*Taper Tap.* The taper tap has straight sides on the point end for a distance of one-fourth the diameter of the tap. The teeth at the shank end are parallel for a length equal to the diameter of the tap.

Fig. 33. Types of Hand Taps: Left—Taper Tap; Center—Plug Tap; Right—Bottoming Tap
*Courtesy of Wiley & Russell Manufacturing Company, Greenfield, Massachusetts*

The teeth between these parallel teeth and the straight sides are tapered. This gives a graduated cutting depth for the teeth, the front teeth cutting less stock than the back. This tap is best suited for starting a thread, but unless the hole goes entirely through the piece that is being tapped there will, of course, be a space in the bottom of the hole equal to one-fourth the diameter of the hole which will not be threaded.

Fig. 34. Wiley & Russell Pipe Tap

*Plug Tap.* The plug tap is most commonly used. It has three teeth on the end, tapered off so that while useful to start the thread, they will bottom a hole sufficiently to take a bolt with a tapered or round end.

*Bottoming Tap.* The bottoming tap is useful to finish out the thread started by a taper tap when the hole does not go entirely through the piece.

There is frequent use in garages for pipe-plug taps, Fig. 34. As will be seen, they are more stocky than bottoming taps, and, of course.

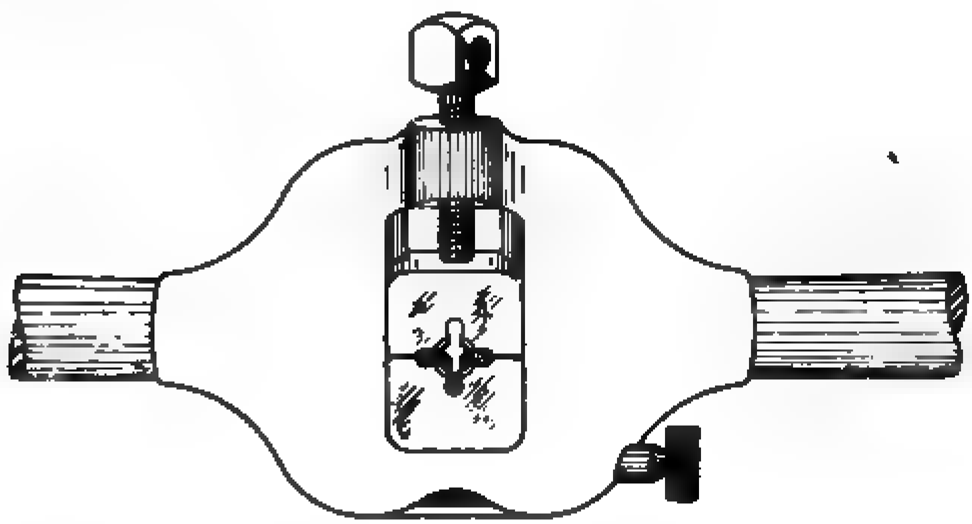


Fig. 35. Threading Die Holder

have a taper throughout the surface of the cutting area to take care of the taper threads required by a pipe plug.

**Tapping Process.** It must be remembered in using taps that, because of the nature of the work they are called upon to do, they are tempered hard and the cutting edges are very brittle; they must, therefore, be handled with great care. In hand tapping the process

Fig. 36. Two Forms of Adjustable Dies; Left—Card Die with End Taper Screw; Right—Wiley and Russell Die with Side Taper Screw

simply cannot be rushed; the tap must be turned slowly forward about half a turn and then back, advancing the wrench a little each time with an even stroke. As previously mentioned, a wrench must be used which fits over the square end. The pressure of both hands operating the opposite handles of the wrench must be even.

**Dies.** There are two kinds of dies. One is the split type which requires several settings before the thread is completed and the other

which completes the work in one operation. The first kind is shown in Fig. 35, the assembly consisting of a stock or wrench in which the cutting die is held. These dies, for a specified size, may be opened up until the cutting edges will slide over the work and then, when fully closed, will give the completed thread of the correct dimension.

Dies which complete the thread in one operation are made adjustable for wear. They are made up in a solid round piece with one side cut away with a slot, as shown in Fig. 36, so that wear may be taken up by means of a taper-set screw.

Oil should always be used in abundance on taps or dies. When one is threading steel or malleable iron, it is well to turn the die back after every three or four turns forward.

In cutting threads with taps and dies in the lathe, the speed with which the tools may be operated is a very important consideration. Cast iron, brass, and aluminum can be threaded at a much higher speed than steel, but a tap or die must not be run as fast as a drill. A speed of 10 feet per minute in hard stock is a fair average.

## REAMING

**Function of Reamer.** Reamers find their place in the production of round, straight, and smooth holes, uniform in diameter, as required

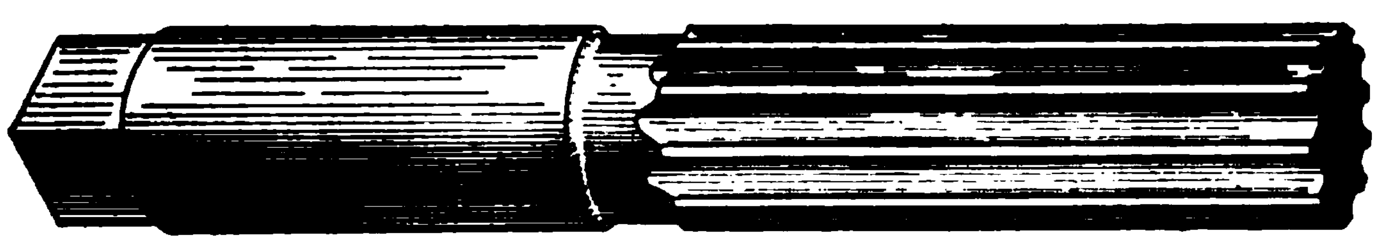


Fig. 37. Solid Hand Reamer

in the construction of accurate machinery, requirements which a drill cannot always be relied upon to meet. The reamer is a sizing tool

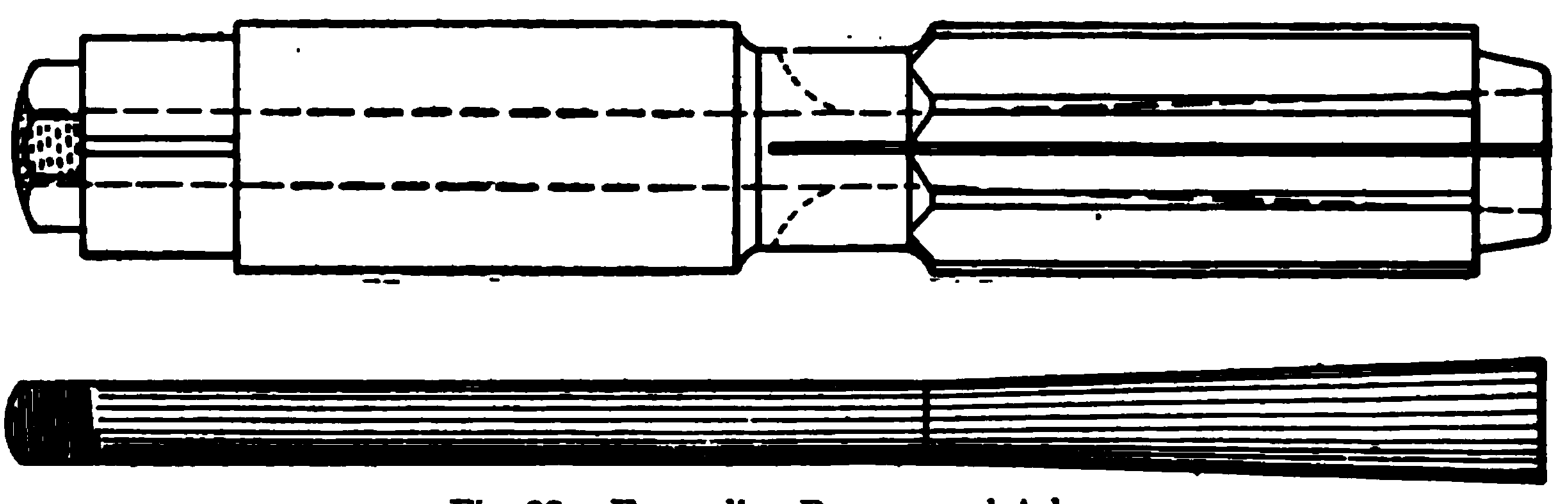


Fig. 38. Expanding Reamer and Arbor

having two or more teeth either parallel or at an angle with each other, the latter forming what is known as a taper reamer. These

teeth may be either straight or spiral, a spiral tooth producing a shearing cut and a straight tooth a square cut.

The construction of reamers divides them into two general classes—solid, and adjustable, or expansion, types. A solid reamer, Fig. 37, has a shank and teeth made from a single piece of tool steel. All taper reamers come under the solid class. The expansion reamer is a built-up tool, the usual form consisting of a shank and head, with an expanding arbor passing down through the center, Fig. 38. As adjustment to compensate for wear only is attempted, the amount of expansion is small.

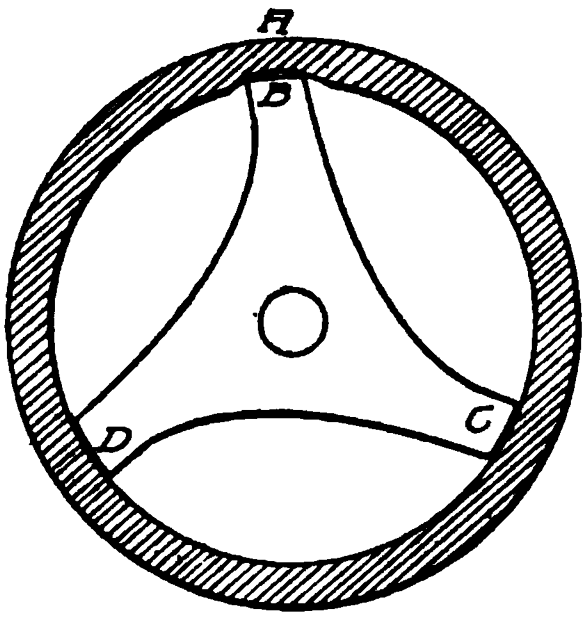


Fig. 39. Diagram Showing Action of Three-Lipped Reamer in Irregular Hole

**Number of Teeth.** Number, form, and spacing of teeth are important considerations. Reamers having fewer than five teeth are not to be used where an accurate cylindrical shape is desired. A reamer having three teeth cannot be depended upon to produce round holes, inasmuch as any irregularity in the hole being reamed affects the cutting of the tool. For example, suppose a depression *A*, Fig. 39, exists in the drilled hole; if tooth *B* comes to this point and drops in, the cutting of *C* and *D* is decreased, thus producing a hole that is not round. The same effect to a lesser degree is shown in Fig. 40. When the cut is relieved at *A*, the pressure of the cut *C* will crowd the tool toward *E*. Since the pressure of the cut at *B* and *D* balance each other, any decrease of the cut at *C* causes an increase at *D*, and *B* and *C* will overbalance *D*, the body of the reamer moving an appreciable distance toward *E*. With five or more teeth this effect practically disappears. The more cutting edges, the more smoothly will the reamer work. The construction of adjustable reamers does not admit of as many teeth as can be formed on a solid reamer, yet the advantage of adjustability to a certain extent offsets this.

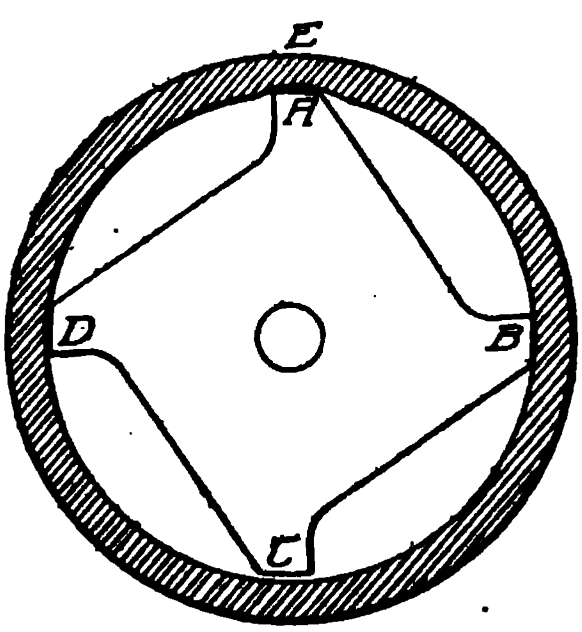


Fig. 40. Diagram Showing Action of Four-Lipped Reamer in Irregular Hole

Where reamers have a number of teeth equally spaced, they do not produce so good results as those having an odd number of teeth. In the former, the teeth fall opposite each other, causing greater tendencies to vibration, and in the case of reaming irregular holes, the greatest cut will be carried on two opposite teeth. With an odd number of teeth the greatest cut must be carried on at least three teeth. Extensive use of reamers having an even number of teeth irregularly spaced is common. This gives practically the same effect as having an odd number of teeth.

**Clearances.** Grinding of the clearance on top of the tooth is an important point in the construction of a reamer. The clearance should be sufficient properly to relieve the cutting edge, as shown in Fig. 41. If too great a clearance is given, the tooth will be weak and chatter in the work. As is frequently produced, the cleared surface is slightly concave, the amount depending upon the diameter of the emery wheel used in grinding it. As a plane surface is desirable, a wheel of large diameter which gives approximately such a surface should be employed, or better still, the face of a cup emery wheel which gives a straight clearance.

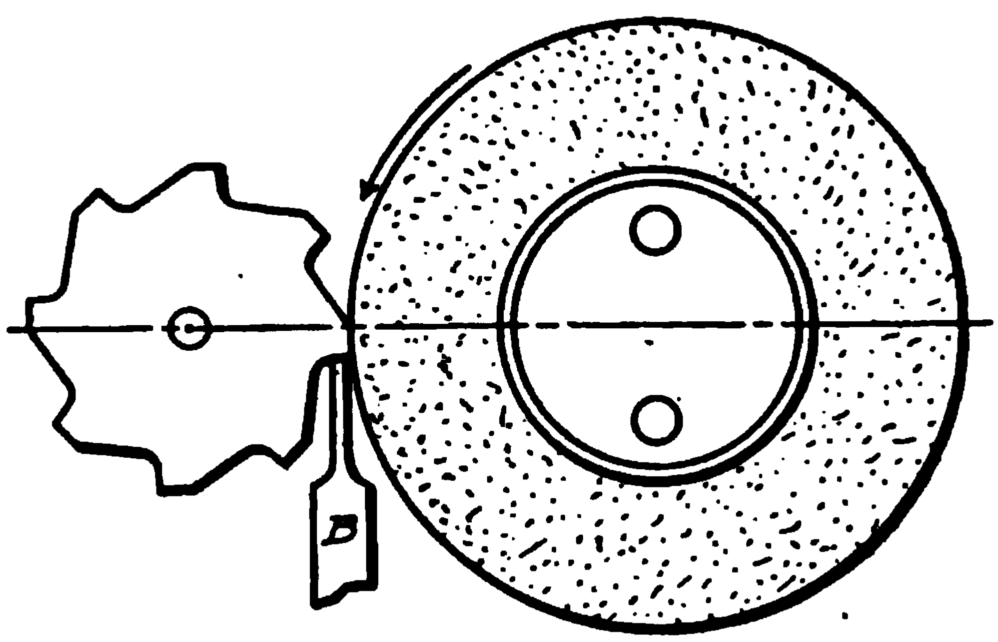



Fig. 41. Diagram Showing Method of Grinding Reamer for Clearance

*Clearance Angle.* Clearance angle will depend largely on the distance the axis of the emery wheel is set back of the axis of the reamer. In no case must the wheel come in contact with the front face of the tooth being ground on the one next behind, and the guiding finger which steadies the reamer must always bear against the front face of the tooth being ground. When the diameter of the reamer is large and the pitch of the teeth so small that the necessary clearance cannot be given except by using too small an emery wheel, the wheel can be mounted on an axis at a considerable angle to the axis of the reamer. This produces a plane surface, but because of the wear of the emery wheel, it is not so satisfactory as the use of the cup wheel.

The wheel must be so placed as to cut its entire width, otherwise it will be grooved and the cutting edges of the tooth rounded off.

**Characteristics of Hand Reamings.** Reamers for hand use are made in two lengths, what is known as the *short* reamer being considerably shorter both in the flute and in the shank than the regular, or *jobber's*, reamer. The diameter of the point is about $\frac{1}{64}$ inch under size, the tool tapering to exact diameter at about one-fourth of the length of the tooth from the point. The remainder of the teeth are ground nearly parallel, the diameter of the shank end being from .0005 to .00075 inch small. This slight taper counteracts the tendency that all reamers have to ream a hole slightly over size at the top, which is due to the tool remaining longer in contact with the wall of the hole at the top than at the bottom. The limit of error allowed in their manufacture does not exceed .00025 inch.

**Kinds of Reamers.** The *spiral-fluted reamer* always is cut with a left-hand spiral. It gives a smooth shearing cut and is especially

Fig. 42. Reamer with Inserted Blades
*Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island*

valuable for machine reaming on centers as it does not tend to draw into the work and off from the center. They are also made in shell and taper form.

A *fluted chucking reamer* with a taper shank is not unlike a hand reamer. The teeth are short and slightly tapered at the point, which facilitates starting when used against the dead center of a lathe.

The *three-flute chucking reamer* has a long shank, and the fluted portion is ground cylindrically true and is especially adapted to the reaming of deep-cored holes.

Those classes of adjustable-blade reamers in which each blade is set out independently, Fig. 42, should be reground after each adjustment, as it is almost impossible to set the blades out equally. In using a reamer it should be turned continually forward. Never turn it backward for withdrawal, as this is likely to injure the tool. Oil should be used freely in reaming steel or wrought iron. Cast iron and brass are usually reamed dry. A small amount of oil, however, frequently improves the quality of work in these metals.

## FITTING TAPER PINS

**Determining Amount of Tapes.** In order to set the slide rest of the lathe at the proper angle for boring or reaming any degree of taper, measure the diameter of the circular rest-seat, Fig. 43, and

Fig. 43. Compound Tool Slide Rest

describe a circle of that diameter on a flat surface, marking the center of the circle and drawing a radial line *AH*, Fig. 44; mark off on *AH* a distance *AB* equal to the diameter of the small end of the taper hole to be bored and draw the line *AG* at right angles to *AB* and of a length equal to the length of the taper to be bored. Draw *GB* parallel to *AB* and of a length equal to the diameter of the large end of the taper. Connecting *D* and *B*, the distance *EF* measured on the circumference of the circle between the lines will equal the amount that the rest must be swiveled to cut the desired taper.

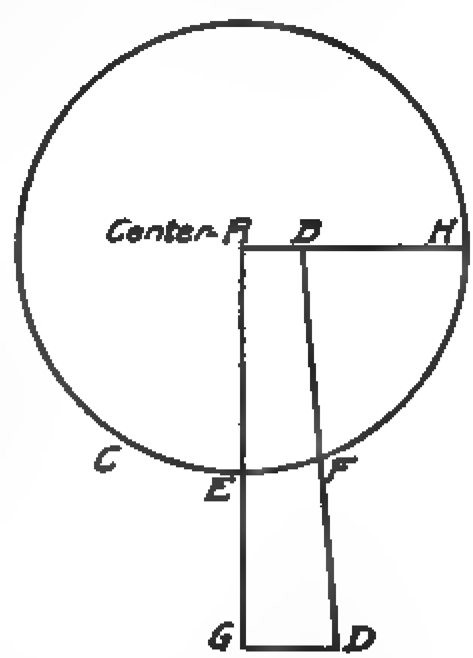


Fig. 44. Diagram for Determining Slide Rest Setting to Give Certain Taper

**Reamers and Taper Pins Available.** The Pratt & Whitney Company makes standard taper reamers with a taper of $\frac{1}{16}$ inch per foot and diameters from $\frac{1}{4}$ inch up; also 4-inch length of flute up to 2 inches in diameter; finally they make 18-inch length of flute, diameters advancing by 16ths and 32nds. The Pratt & Whitney standard taper-pin reamers taper $\frac{1}{4}$ inch per foot and are made in fifteen sizes.

Brown & Sharpe make eighteen sizes of tapers ranging from 0.20 inch to 3 inches in diameter at the small end; taper 0.5 inch to 1 foot, except the number 10, which is 0.5161 inch per foot.

The Jarno taper is 0.05 per inch, or 0.6 inch per foot. The number of the taper is its diameter in tenths of an inch at the small end, in eighths of an inch at the large end, and the length in halves of an inch. Thus, No. 3, Jarno taper is 1½ inches long, 0.3 inch in diameter at the small end and ⅜ inch in diameter at the large end.

### HAND KEYSEATING

Hand keyseating is that process of cutting a groove into a piece of metal into which a key will fit accurately. The need of accuracy in keyseating is the great drawback to the hand method inasmuch as it is a tedious job to cut a true seat with a chisel.

**Keyseating Process.** The roughing out of the keyseat is done by chipping, a process already described. The first thing to determine is the size of the keyseat, and this is obtained from the S.A.E. table of standard sizes of keyseats, Table IV. It is well to have a chisel with a cutting surface about ⅛ inch smaller than the width of the keyseat to be cut, although with a large keyseat a smaller chisel will do the work but with somewhat more cutting. A cape chisel, Fig. 4, is the tool used for keyway cutting.

**Laying Out the Keyway.** The next operation is to very carefully mark off the keyway with scratched lines or chalk, the distance between the lines to be from $\frac{1}{16}$ to $\frac{1}{16}$ inch less than the width of the key. Use these lines to guide the chisel and cut the keyway to a depth approximately within $\frac{1}{16}$ inch of the depth of the finished keyway. One must always leave sufficient stock on the sides and bottom of the keyway for an accurate finish filing.

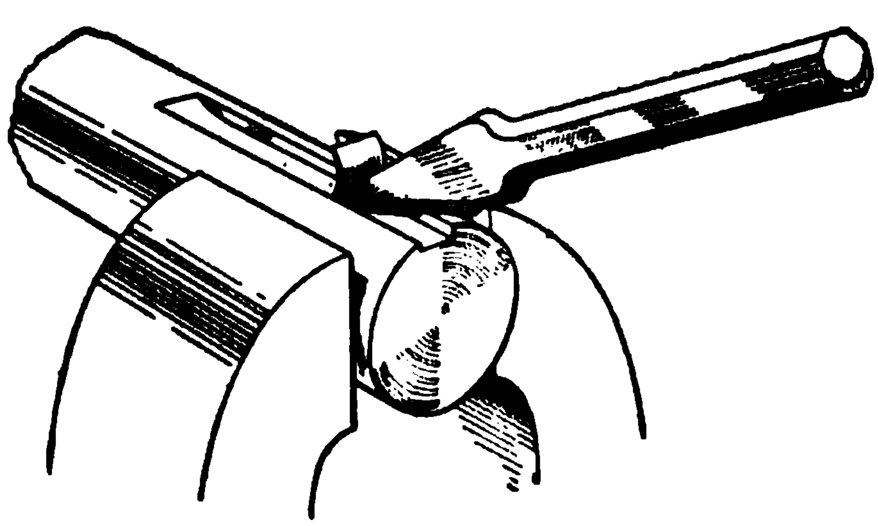


Fig. 45. Chipping Keyseat in Round Shafting

*Chipping.* The work is held in a vise, and the chipping is done by grasping the chisel firmly with the left hand, holding the cutting edge to the work and striking the head of the chisel with the hammer, Fig. 45. The eyes must be kept on the cutting edge of the chisel to

## TABLE IV

### Standard Sizes of Keyseats

For straight keys, height of keyseat = $D$
For feather keys $D = \frac{1}{2}A$
Keyseat in shaft same depth as $D$ in small end
Standard Taper = $\frac{1}{8}$ inch per foot.

| Size of Bore (in.) | $A$ Width (in.) | $D$ Smallest Height (in.) | Size of Bore (in.) | $A$ Width (in.) | $D$ Smallest Height (in.) |
|---|---|---|---|---|---|
| 1 to $1\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{3}{32}$ | $3\frac{11}{16}$ to $3\frac{7}{8}$ | $\frac{15}{16}$ | $\frac{5}{16}$ |
| $1\frac{3}{16}$ to $1\frac{3}{8}$ | $\frac{5}{16}$ | $\frac{7}{64}$ | $3\frac{15}{16}$ to $4\frac{1}{8}$ | 1 | $\frac{11}{32}$ |
| $1\frac{7}{16}$ to $1\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{1}{8}$ | $4\frac{3}{16}$ to $4\frac{3}{8}$ | $1\frac{1}{16}$ | $\frac{11}{32}$ |
| $1\frac{11}{16}$ to $1\frac{7}{8}$ | $\frac{7}{16}$ | $\frac{9}{64}$ | $4\frac{7}{16}$ to $4\frac{3}{4}$ | $1\frac{1}{8}$ | $\frac{3}{8}$ |
| $1\frac{15}{16}$ to $2\frac{1}{8}$ | $\frac{1}{2}$ | $\frac{11}{64}$ | $4\frac{13}{16}$ to $5\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{27}{64}$ |
| $2\frac{3}{16}$ to $2\frac{3}{8}$ | $\frac{9}{16}$ | $\frac{3}{16}$ | $5\frac{5}{16}$ to $5\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{29}{64}$ |
| $2\frac{7}{16}$ to $2\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{13}{64}$ | $5\frac{13}{16}$ to $6\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ |
| $2\frac{11}{16}$ to $2\frac{7}{8}$ | $\frac{11}{16}$ | $\frac{15}{64}$ | $6\frac{5}{16}$ to $6\frac{3}{4}$ | $1\frac{5}{8}$ | $\frac{17}{32}$ |
| $2\frac{15}{16}$ to $3\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $6\frac{13}{16}$ to $7\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{19}{32}$ |
| $3\frac{3}{16}$ to $3\frac{3}{8}$ | $\frac{13}{16}$ | $\frac{17}{64}$ | $7\frac{5}{16}$ to $7\frac{3}{4}$ | $1\frac{7}{8}$ | $\frac{5}{8}$ |
| $3\frac{7}{16}$ to $3\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{19}{64}$ | $7\frac{13}{16}$ to $8\frac{1}{2}$ | 2 | $\frac{21}{32}$ |

watch the progress of the work. The beveled side of the chisel is the guiding surface and this should be held at a very slight angle with the surface of the work that is being cut. Of course, to increase or decrease the amount of the cut, it is only necessary to raise or lower the chisel. If the hand is carried too low, the tool will run out before the end of the cut; while if the hand is carried too high, the chisel will gouge into the stock and make the progress of the work slow. In steel, malleable iron, and cast iron, the depth of the cut should vary from $\frac{1}{16}$ to $\frac{1}{8}$ inch, but should never be greater than the latter figure.

*Chipping Malleable Iron and Steel.* When chipping malleable iron or steel, one should keep on the work bench a piece of waste or cloth saturated with oil. After each complete cut is made through the work, the chisel should be rubbed in this waste or cloth. This lubricates the cutting edges and prolongs the life of the chisel.

**Finish Filings.** It is in the finish filing that the greatest accuracy must be observed. It is not advisable to attempt cutting keyways to an accurate size by the use of inside calipers or other measuring instruments; it is best to have at hand the key which is to be fitted into the keyway. As the work of filing progresses, test the key in the keyway at frequent intervals. The sides and bottom should be filed at the same time, and it is quite important that the proper width of file be obtained. One should so file the keyway that the bottom and sides will be cut down to the proper size at about an equal rate. The key must not be a loose fit but a press fit within the slot.

**Woodruff Keys.** Although it is a very difficult and time-consuming task, it is possible to cut Woodruff keys with a chisel. These are "half moon" keys, the radial surface serving to lock the key into the seat after the matching keyways are fitted over it. The cut and try process is the only method to use in fitting Woodruff keys. Have the key at hand and chip the concave keyway, using the key as a pattern.

## RIVETING

**Brake Linings.** *Types of Rivets.* Rivets used for brake linings are of three kinds, the flat head, countersink, and split rivets, Fig. 46. The former is headed like an ordinary nail and may be procured in a number of head-diameter sizes. The countersink rivet has a head which is flat on top and tapered underneath to fit a countersunk hole. The split rivet has a countersunk head with a split shank to permit the bending over of the ends like a cotter pin.

The split rivet with countersunk head is the easiest rivet to handle in relining brake bands. It is not well to use the old brake lining as a pattern for a new one, but a new one should be cut. Wrap new lining around the band, being sure that it is tight all around the surface and cut it off the right length, allowing no overhang.

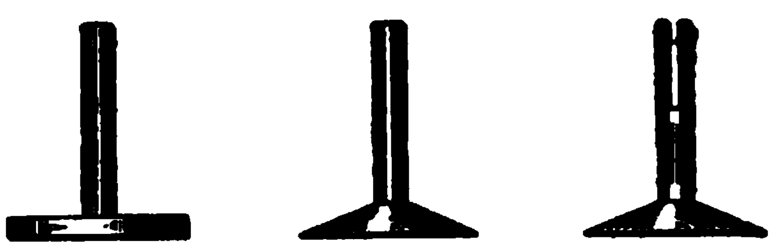


Fig. 46. Types of Rivets for Brake Linings

*Riveting the Lining.* Fasten the band in the vise with the convex surface up and one end within the jaws of the vise. Procure a drill the size of the rivet holes in the brake band. With a sharp instrument prick the brake lining through the two end rivet holes and drill the lining through. Then countersink these holes so that the top surface of the rivet is very slightly below the top of the lining. Do not countersink so deep that the rivets will pull through. Now insert the copper rivets through the lining and brake band. If split rivets are used, proceed as follows: Select a bolt of such a size that it will give a firm seat for the head of the screw and fasten it in the vise with the threaded end up. Place the rivet head against the end of the bolt, spread the two ends of the split rivet with a screwdriver, and then pound them firmly against the band with a hammer. If solid head rivets are used, the head should be riveted solidly with the round end of a machinist's hammer.

Proceed around the band with consecutive rivets, keeping the lining stretched firmly at all times.

**Clutch Facings.** The most common cause of faulty cam-clutch action is some defect of the leather facing. When one has determined that the facing needs replacement, he is confronted with the proposition of installing a new leather, and here is where one must have a working knowledge of the proper methods of riveting.

*Proper Clutch Leathers.* Just a word about clutch leathers. If one decides that a leather must be replaced, then it is the best plan to replace it with a new one from the factory of the maker of the automobile. Of course, it is not a difficult matter to cut a clutch leather (see instructions in Gasoline Automobiles, Part IV), and if the garage has a stock of good clutch leathers, then cutting your own is the simpler plan. One difficulty, however, is that the quality and thickness of the leather you purchase may not be suited at all to the clutch upon which it is to be put. The factory leathers are of a material and size specified by the engineers of that factory and are the right ones to use.

*Preparing the Leather.* Before riveting the new leather in place it should be made as pliable as possible by soaking it in neat's-foot or castor oil. This soaking should be carried on until the oil has penetrated the leather from surface to surface. Do not soak the leather in water with the idea that it will fit more tightly over the cone; there is a big chance of its shrinking too much and pulling away from the rivets.

*Putting Leather on Clutch.* It is best to purchase the leather in endless form, that is, sealed at the ends so that it will fit perfectly over the cone. First, place the leather on the cone with one side flush with the large diameter of the cone. Then pry the leather on until it is evenly fitted to the metal surface. If the leather hangs over the small-diameter edge of the cone, it is not on far enough and should be pried farther over the edge of the taper. No trouble should be experienced in fitting the leather by the use of the hands only.

*Riveting Process.* The holes in the leather should be countersunk deep enough so that the rivet heads will be below the surface and yet not so deep that there will be danger of the leather pulling away from the rivets. Incidentally, after the leather facing has been applied, it is well to rub off the high spots of the leather with

### TABLE V

**Proportions for Riveted Steel Plates with Iron Rivets**

| | Inch | Inch | Inch | Inch | Inch |
|---|---|---|---|---|---|
| Thickness of plate | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ |
| Diameter of rivet | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ |
| Diameter of rivet hole | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 |
| Pitch—single riveting | 2 | $2\frac{1}{16}$ | $2\frac{1}{8}$ | $2\frac{3}{16}$ | $2\frac{1}{4}$ |
| Pitch—double riveting | 3 | $3\frac{1}{8}$ | $3\frac{1}{4}$ | $3\frac{3}{8}$ | $3\frac{1}{2}$ |

the edge of a piece of glass. Insert a rivet through one of the countersunk holes in the leather, which, of course, matches up with a hole drilled through the clutch cone. Flat-headed countersink rivets of copper should be used, the rivets being long enough to project $\frac{3}{16}$ inch through the clutch cone. Place a bolt with the head ground slightly flat in a vise, the head end being up. Hold the rivet in the clutch leather against the bolt head and hammer a head on the rivet with the round end of a ball-peen hammer. Duplicate this operation for each of the rivets.

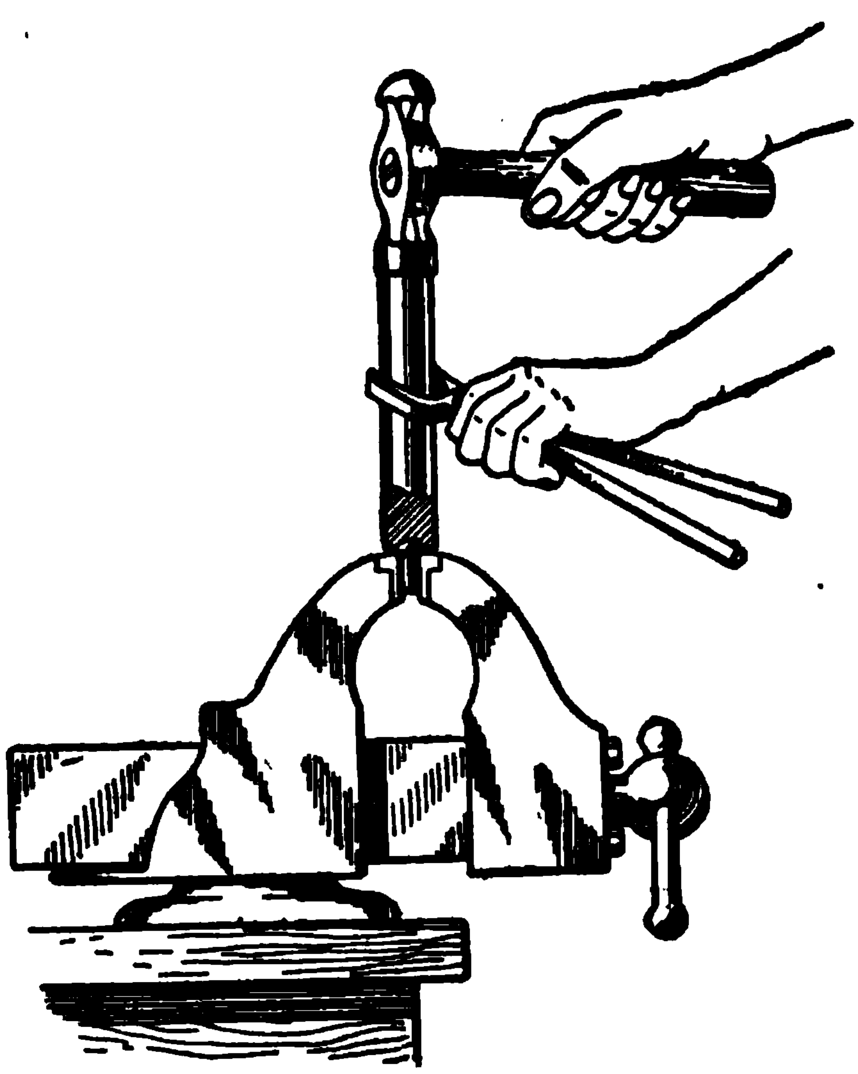


Fig. 47. Easily-Made Type of Rivet Set

**Cold-Riveting Metals.** Rivets are used to hold together two or more pieces of sheet metal and are employed in the assembly of frames, the supporting of spring hangers, etc. Table V gives the proportions for riveted joints in steel plates with iron rivets. Cold riveting can be applied to work where accuracy is not a requisite and the rivets are of small size, as in sheet metal work.

**Hot-Riveting Metals.** For hot-riveting work there are two general classes of rivets used: countersunk rivets and flush rivets, Fig. 47. Flush rivets are used to support the spring hangers to the frame and in riveting cross-members to the frame, etc. Countersunk rivets are used cold in brake lining facing and clutch facing, as previously described, and in joining pieces where clearance is a factor, as in riveting the ring gear to the differential case flange.

*Rivet Set.* In heading large rivets, it is always advisable to use a rivet set, and in the case of riveting the ring gear to the differential case flange this tool is essential. The rivet set is a tool with a spherical depression in the end. When this spherical depression is applied to the shank end of a rivet and the rivet set is hammered, the end of the rivet will be headed over in a nicely rounded head. It is the only way that accurate riveting can be accomplished.

**Installing New Ring Gear.** Usual rivet sizes for use in fastening the ring gear to the differential housing flange are $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ inch. The rivets used are round-headed or countersunk and are made of iron. To do a good job of installing a new ring gear proceed as follows:

*Removing Old Gear.* The first thing to be done is to remove the old gear. This is done by cutting off the rivet heads with a sharp chisel in the manner shown in Fig. 3. If the rivet is countersunk, the head may have to be drilled out to remove it. After the gear is off, go over the surface of the differential housing flange with a file—especially over the rivet holes—to remove any burrs or irregularities in the metal which would cause an untrue seat and thus throw the ring gear out of line. Do the same thing on the face of the ring gear which is to fit against the differential housing flange.

*Heating Rivet.* Although this job may be done by cold riveting, the hot method is a stronger and truer assembly because it permits more accurate seating and firmer fastening of the rivets. The rivets should be of such a length that they will extend beyond the flange a distance equal to one and one-half times the diameter of the rivet. The rivets should be placed through the flange and gear in consecutive order but alternating in direction; that is, the head of one rivet should go through in one direction and the head of the rivet next to it in the other direction.

One of the best methods of heating the rivets is by means of an oxy-acetyline flame, although they may be heated in a forge as well. The rivets must be put into the holes red hot, as they are more easily headed over, and, in addition, the shrink in the rivets as they cool draws the pieces closer together. The constant hammering in forming the head thoroughly fills the hole.

*Making Rivet Set.* If one does not desire to purchase a rivet header, it is not hard to make one. One of the simplest ways is as follows: Procure a bar of round steel about twice the diameter of

the head of the rivet. Fasten one of the rivets in a vise with the shank within the vise and the under side of the head flat against the top of the vise jaws. Now heat one end of the bar to a white heat and drive the heated end against the round rivet head, thus making a depression in the end of the bar, Fig. 47. It will probably be necessary to reheat the bar two or three times, using a new rivet each time, to get the depression deep enough. This depression should be of such depth as to take in the entire head of the rivet. Another method is to drill the depression into the end of the bar, thus giving a V-shaped depression. Such a depression will serve nearly as well as the round one for the work at hand.

*Heating the Rivet.* It is now assumed that one has rivets, red hot, in the forge, a rivet set of the proper size, and that an anvil or a block of steel or iron, upon which the riveting may be done, is available. Extract one of the rivets from the forge with the tongs and insert it quickly into the rivet hole. It is imperative that the work be done quickly, so that the final heading is completed before the rivet has had a chance to cool. The head of the rivet is dropped down against the anvil or block of iron or steel. With the assembly held firm against the anvil or block, place the rivet set over the shank of the rivet and hammer with quick light strokes against the other end of the rivet set with a fairly heavy machinist's hammer. Convenience and quick work demand that this be made a two-man job, one to hold the work and the other to do the riveting. In shaping the head, oscillate the rivet set in the hand so that the head will be evenly rounded on all sides. A properly shaped rivet head should be very nearly the same shape as the head, which was a part of the rivet in its original form, as shown in Fig. 48 A. A well-rounded head is stronger than one which is more or less flat and which spreads over a larger area. In Fig. 48 B is shown the section of a countersunk head joint.

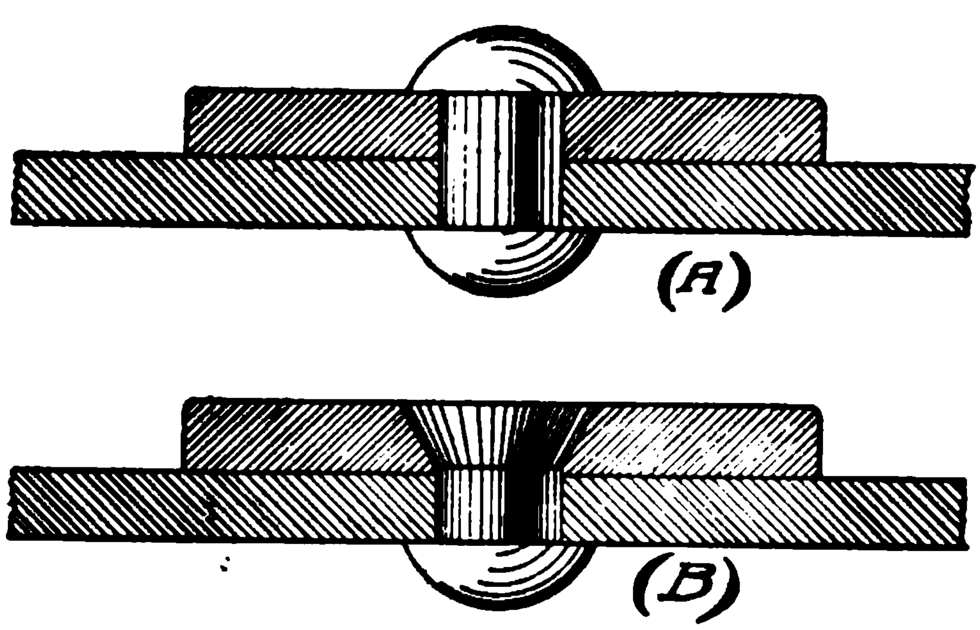


Fig. 48. Section of Rivets in Place

Fig. 49. Modern Motor-Driven Forge
*Courtesy of Canedy-Otto Company, Chicago, Illinois*

## FORGING

**Forging Equipment.** *Forges.* Many of the jobs in a repair shop require the use of a forge, two kinds being necessary for all well-equipped shops. Forging and welding are easily cared for by the power-driven blower forge, Fig. 49. This type of forge is made of steel and the medium size is best for automobile repair shop work. For brazing, melting babbitt metal, hardening, tempering, annealing, and heating soldering irons, it is best to use a gas forge that takes its air from the tank of the air-compressor outfit and its gas from the regular city or town mains. Portable gasoline forges, Fig. 50, are obtainable and work equally well. It is well to have also a small hand torch, Fig. 51, for use in smaller brazing or soldering jobs.

Fig. 50. Double-Jet Brazer
*Courtesy of Turner Brass Works, Chicago, Illinois*

It is well to set up these two necessary forges with a bench between them. The bench

should have a large drawer and a good vise attached to it, and will be found useful both in brazing and soldering processes; the drawer can be divided into compartments, one to hold the blacksmith tools and the other the soldering irons and sheet-metal tools. The vise will come into use innumerable times at either forge.

Fig. 51. Hand Gas Torch for Brazing

*Tools*. The remaining equipment is simple. A medium size anvil, Fig. 52; two sledge hammers, medium and heavy; three, or perhaps four, forge hammers; tongs for holding round, flat, and irregular work; tools for cutting off material, both hot and cold; and finally flatting and swaging tools. Melting ladles can be placed over either coal or gas flame, and either forge can be used in melting the antifriction metals used in lining bearing boxes.

**Blacksmithing Repair Outfit.** A complete blacksmithing outfit that is adequate for ordinary repair shop work can be purchased for approximately $50. This will give a forge that uses coal as a fuel, a vise, a set of taps and dies, anvil, drill press, hammers, drills, tongs, wrenches, and a few small tools. Some of the tools that apply strictly to horseshoeing can be applied to the repair of automobiles. These consist of a farrier's hammer, knife, and pincers. All of the other tools mentioned apply to general metal work. A post drill will be found very practical for shops not provided with power. As complete sets of drills usually accompany the post-drill outfit, it is not necessary to stock up on a variety of tongs, for these can be made best to suit the purpose for which they are to be used.

Fig. 52. Anvil Fastened to Block

**Electric or Gas Furnaces.** If the shop is a large one, there probably will be considerable tool dressing that will require heat-

treating of various parts, and an electric furnace may be procured to handle this class of work. With a furnace of this kind, the amount of heat may be regulated within close limits, and temperatures may be reached that are sufficiently high for hardening, carbonizing, or annealing any pieces within the range of the furnace. It is questionable whether a furnace of this kind would be practical, except for large shops where there is much of this class of work to be done. Furnaces of the gas- or oil-burning types, Fig. 53, are probably more serviceable and less expensive than the electrically heated form. Welding is a very useful repair process in automobile work and it will be found fully treated in another article.

**Heat Treatment.** Since there is an almost universal use of high-grade alloy steel in automobile construction, it is quite necessary that the repair man have some knowledge of heat treatment of the various metals. It must be known that metals of this character cannot be machined unless they are annealed and are of but little greater value than the ordinary machinery steel parts if they are not properly heat-treated to bring out the physical characteristics desired after fabrication.

Fig. 53. Simple Gas Furnace
*Courtesy of American Gas Furnace Company, New York City*

*Tempering Steel.* The simplest method of tempering steel is the old-fashioned method of only partly cooling the tool when quenching it, then quickly withdrawing it, polishing off its working surface, and letting the heat which remains in the tool produce the required temper as judged by the color. When first quenched, the point of the tool is the coolest and, on withdrawing it, the heat in the balance of the tool heats up the point, changing its color from light straw to deep straw, then light brown, darker brown, light purple, dark purple, dark blue, light blue, and finally blue tinged with green and black. When black appears, the

temper is gone. When the color desired is reached, the tool should be completely quenched.

The following tabulation shows the temperature in degrees Fahrenheit at which steel assumes certain colors.

| Degrees | Color |
|---|---|
| 430 | Very light straw |
| 450 | Light straw |
| 470 | Dark straw |
| 490 | Very dark straw |
| 500 | Brownish yellow |
| 520 | Yellow tinged with purple |
| 530 | Light purple |
| 550 | Dark purple |
| 570 | Dark blue |

The modern method of tempering is by means of a furnace, as shown in Fig. 54, an oil bath being heated by an oil or gas flame to the proper temperature, as indicated by the thermometer, and the tools immersed in the bath. When they have reached the same temperature, they are lifted out and quenched in a hardening bath. The use of such a furnace makes the tempering of the shop tools more uniform.

*Hardening Steel.* As it is necessary to maintain the steel in the state it was at the moment quenching began, the quenching bath is a very important part of the process of hardening. The better the bath, the more nearly perfection is attained.

Various baths are used for cooling steel when hardening, on account of the different rates at which they cool the

**Fig. 54. Typical Tempering Furnace**
*Courtesy of Strong, Carlisle and Hammond Company, Cleveland, Ohio*

heated metal. An oil bath is used when the steel is wanted tougher and not excessively hard, as the oil cools the steel more slowly than water. Brine or an acid bath is used when the steel is wanted very hard, as they absorb heat more rapidly than water. For excessively hard work, mercury or quicksilver is sometimes used, as it absorbs the heat very rapidly.

*Self-Hardening Steel.* Self-hardening steel is used to a large extent in modern practice for lathe tools, much being used in the shape of small square steel blades held in special holders, as Fig. 55. Self-hardening steel, as its name indicates, is almost self-hardening by nature; generally, the only treatment that is required to harden the steel being to heat it red hot and allow it to cool. Sometimes the steel is cooled in an air blast or is dipped in oil. It is not necessary to draw the temper. The self-hardening quality of steel is given to it by the addition of chromium, molybdenum, tungsten, or one of that group of elements, in addition to the carbon which ordinary tool steel contains. High-speed steel is lower in carbon.

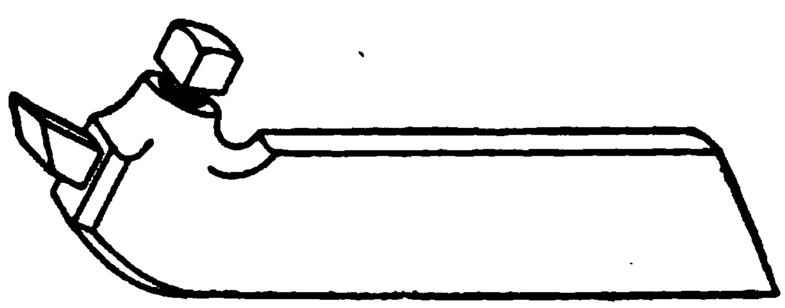


Fig. 55. Tool Using Self-Hardening Steel Blade

Self-hardening steel is comparatively expensive, costing from 40 cents and upward per pound, some of the more expensive grades costing $1 or so. However, when in use, self-hardening steel will stand a much higher cutting speed than the ordinary so-called carbon steel, and for this reason it is much more economical to use, although its first cost is higher.

Self-hardening steel cannot be cut with a cold chisel and must be either cut hot or nicked with an emery wheel and snapped off. Great care must be used in forging it, as the range of temperature through which it may be forged is comparatively slight, running from a good red heat to a yellow heat. Some grades of self-hardening steel may be annealed by heating the steel to a high heat in the center of a good fire and allowing the fire and the steel to cool off together. Steel which has been annealed in this way may be hardened by heating to the hardening heat and cooling in oil.

*Hardening High-Speed Steel.* High-speed steel has a much higher critical temperature than carbon steels. A temperature of about 1350° to 1600° F. is sufficient for carbon steels in general.

High-speed steels require heating from 1800° to 2300° F. and to be cooled in oil such as machine, fish, or linseed.

*Bending Rods.* If a piece of hard tubing is to be bent, it must first be annealed, otherwise it is likely to break. If the piece to be bent is thin-walled tubing, it will collapse. Occasionally, the bending of a moderately thick-walled piece of tubing can be accomplished without heating or filling, although it always is best to fill the tubing before attempting to bend it. If the interior is made solid, or nearly so, with some substance and if the tubing is properly heated and of the right temper, it can be bent to a curve of small radius without damaging the walls of the tubing. It is poor policy to avoid filling the tube by the use of a vise or wrench, or hammer and anvil for bending, as the walls of the tube will suffer and the appearance of the finished work will be unsatisfactory. There are several methods of filling tubing that give good results. Some molten substances can be poured into the tubing, such as resin for thin copper, and brass or lead alloy in steel tubing. The fillers can be removed by heating the tubing after the bend has been made. Some make use of a steel rod when the bending describes a part of a circle, as the filler rod takes the same curve as the tube and thus comes out easily. When many pieces of about the same size of tubing are to be bent, it can be very satisfactorily accomplished with a grooved jig, as shown in Fig. 56.

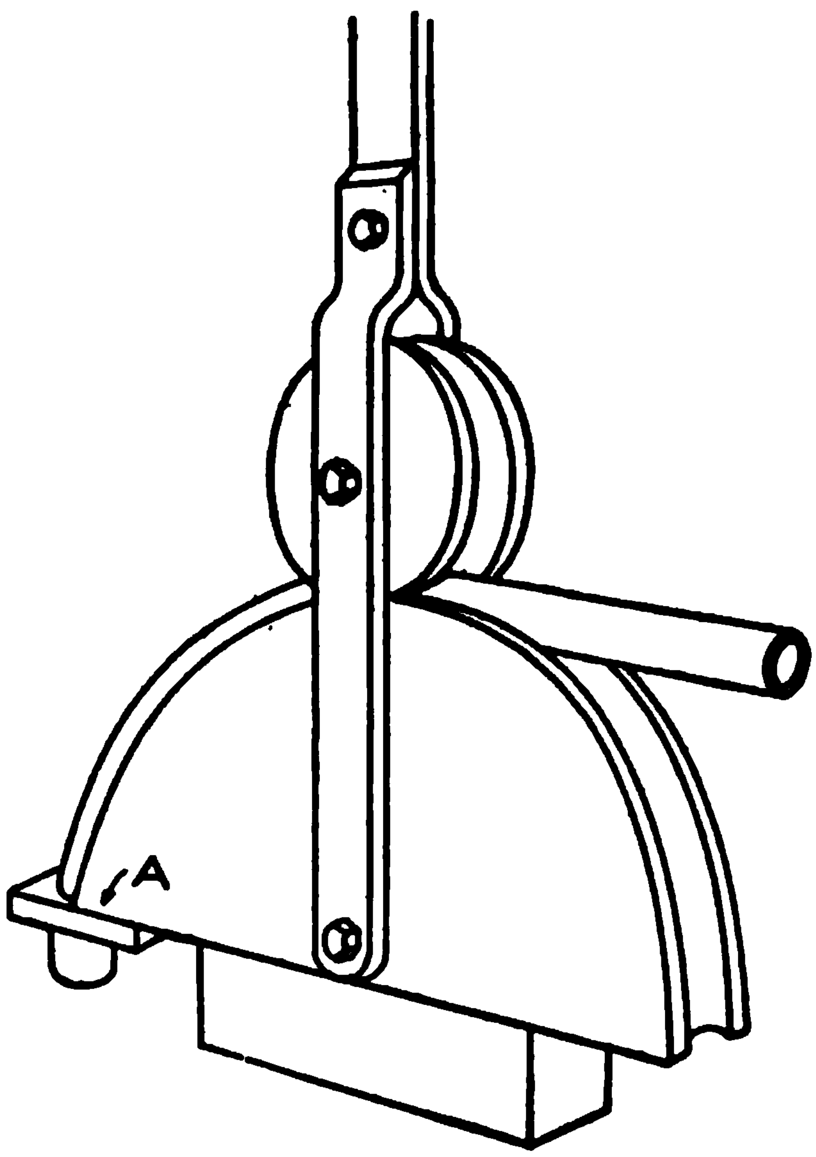


Fig. 56. Grooved Jig for Bending Pipe

## CUTTING GEARS

**Definition of Terms.** In designing or cutting gears, it is quite essential that the terms as applied to this practice be clear to the operator. The nomenclature of gears and their measurements are such that only by diagram, shown in Fig. 57, together with the

following explanation, can one obtain a clear conception of the various measurements:

*Pitch Diameter.* The pitch diameter is the diameter of the *pitch circle.*

*Addendum Circle.* The addendum circle has the same diameter as the outside diameter taken over the points of the teeth.

*Dedendum Circle.* The dedendum circle is known also as the *root circle* and is the circle at the bottom of the teeth.

*Pitch.* Pitch is the distance from the center to the center of the teeth when measured on the pitch circle. Measured in this way, it is called the *circular pitch.*

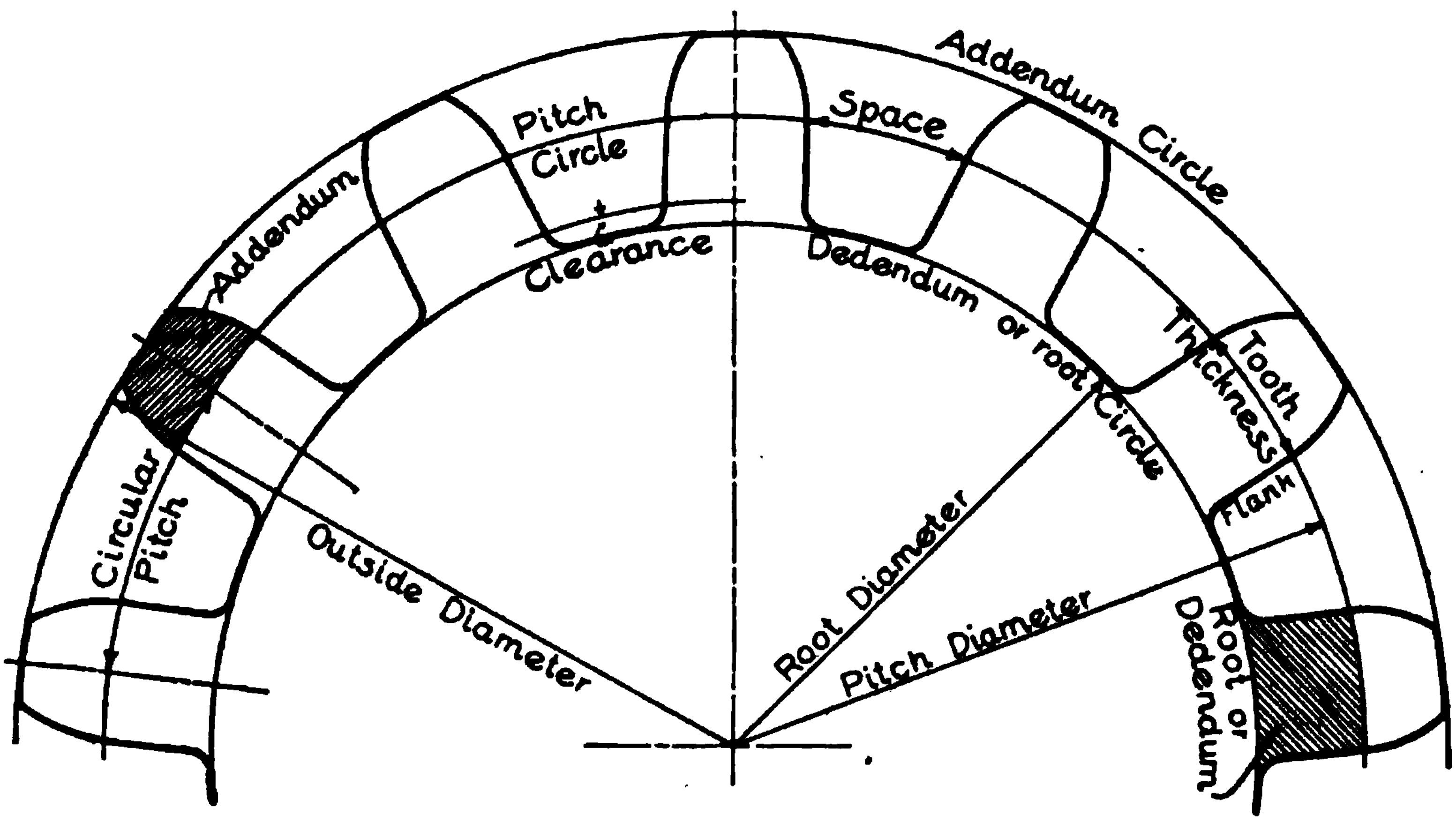



Fig. 57. Names of Tooth Parts

*Face.* The face of the tooth is that part of the curve outside of the pitch circle.

*Flank.* The flank of the tooth is the portion of the curve within the pitch circle.

*Thickness.* The thickness is the width of the tooth, taken as the chord of an arc of the pitch circle.

*Space.* The space is the distance between adjacent teeth, measured as the chord of an arc of the pitch circle.

**Method of Design.** In designing gears two methods are employed, one known as the fixed-pitch method and the other as the diametral-pitch method. The latter perhaps is the more popular since the first involves some tedious calculation, but in the event

that one may wish to apply it, it is well to explain the process and what it means.

*Fixed-Pitch Method.* It once was the practice to design gears on the basis of a fixed distance representing the teeth and this was usually based on the common fractions of an inch. Thus the desired number of teeth multiplied by the given pitch gave the circumference, and the distance, found in this way, divided by 3.1416 gave the diameter of the pitch circle.

Let us suppose that the pitch is divided into fifteen parts, seven of which represent the thickness of the teeth and eight the width of the space. To find the length of the teeth, the pitch is divided into ten parts, of which seven represent the length of the teeth—three parts covering that portion outside of the pitch circle and four parts the length of it, one part being allowed for bottom clearance. Because of the tedious calculation involved in this method, mechanical engineers devised the diametral pitch method.

Diametral-Pitch Method. The diametral-pitch method designates the pitch by a number instead of giving the length of the pitch in inches. This number indicates the number of teeth for each inch of diameter of the pitch circle. Thus, if the diametral pitch is 6 and the diameter of the pitch circle is 10 inches, the gear will have 6 times 10, or 60 teeth. Also, if we know that the pitch is 6—or as usually expressed "6-pitch"—and the gear has 60 teeth, the pitch diameter is $60 \div 6$, or 10. If the gear has 60 teeth and the diameter of the pitch circle is 10 inches, the pitch is $60 \div 10$, or 6-pitch. Three simple rules cover the diametral-pitch method:

(1) *Multiply the diameter of the pitch circle by the diametral pitch to get the number of teeth.*

(2) *Divide the number of teeth by the diameter of the pitch circle to get the diametral pitch.*

(3) *Divide the number of teeth by the diametral pitch to get the diameter of the pitch circle.*

Proportions of tooth parts are determined by rules quite as simple as those of the pitch. These are as follows:

(1) *The addendum is equal to one inch divided by the diametral pitch.* For example, the addendum on a 6-pitch gear will be $\frac{1}{6}$ inch.

(2) *The dedendum is equal to the addendum increased by the clearance, which is equal to $\frac{1}{10}$ the thickness of the tooth on the pitch circle.*

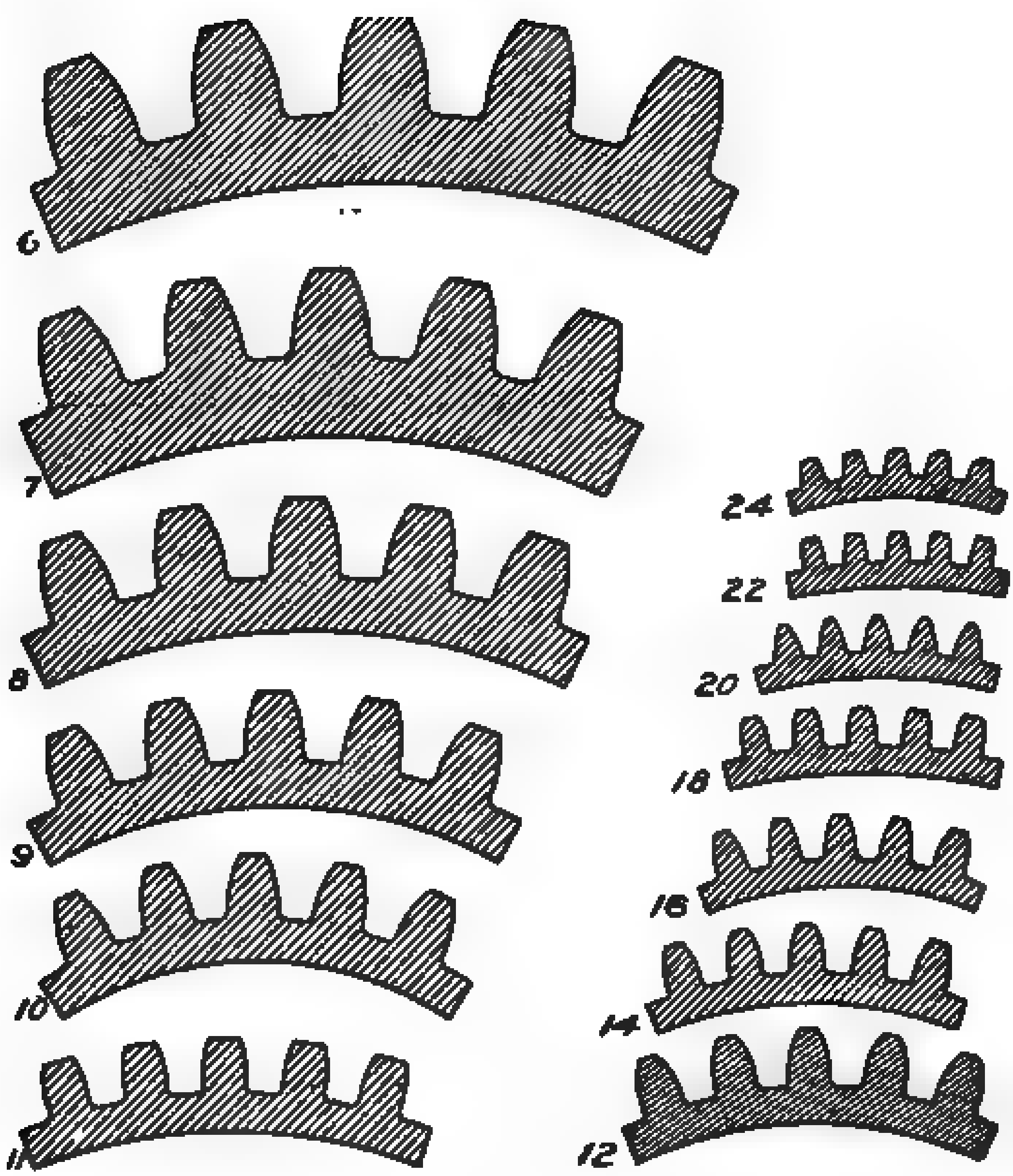



Fig. 58. Proportions of Teeth of Different Diametral Pitches

Determination of the thickness of the tooth and the width of the space at the pitch line is not by the same rule as that given in the former method. In all accurately cut gears, the width of the space exceeds the thickness of the tooth only as much as may be necessary to permit the gear teeth to roll freely together and need not be over .03 of the circular pitch. In cut gears for ordinary purposes, this amount may be doubled, while in gears having cast teeth, it may be necessary to make it as great as 0.10 of the circular pitch, depending largely on the accuracy of the casting. That a clear conception may be obtained of the relative dimensions of spur-gear teeth of different diametral pitches, the gear teeth are shown in full size in Fig. 58. These are the more common pitches. The larger ones are usually 1-, 1½-, 2-, 2½-, and 3-pitch.

## MISCELLANEOUS BENCH METHODS

Best methods for doing work are constantly coming up in all shop work, and the success with which the desired end is attained depends largely upon the skill and judgment of the man in charge. A few examples of the questions likely to arise and suggestions for handling them to give the best solution follow.

**Peening.** Stretching metal on one side of a piece of work is called peening. There is considerable difference between peening and bending. Let us suppose that you have a warped piece of metal to be straightened. If it were to be bent until it were straight, it could be placed on a block with the concave side down and struck with a hammer and driven down past the line of support. This strain would reduce it into an approximately straight line. However, this method could not be applied to a piece of metal with complicated outline for it would remain wavy. In peening to trueness such a piece as that previously mentioned, the piece is placed on an anvil with the convex side down and struck sharp blows with the peen of the hammer on the concave side, with the result that the metal is stretched at the point where the blow is struck. Working successively over the whole surface results in the concave side being stretched so that it is equal in dimension to the convex side, and the piece becomes straight and remains so. Skillful use of the hammer will straighten almost any piece of thin metal. The same process

of stretching the metal is sometimes applied to a hole in a ductile metal which is too large. Possibly a screw has worked the threaded hole too large, but by peening the metal around the hole with a hammer and prick punch, the fit is made tight again. Such a method is not good shop practice but accomplishes a quick repair.

**Drilling Hard Metals.** When a hole is to be drilled in a very hard metal, the drill must also be very hard and must be run at a relatively low speed. The drill must be forced against the metal with as much pressure as possible without breaking the point and an abundant supply of oil is necessary. A drill may be excessively hardened by heating it to a dull red in a charcoal fire and quenching it in mercury instead of in water to make the cooling more rapid. Nicking the surface of the metal with a cold chisel also will give the drill a start, and beneficial results are obtained by using turpentine in place of oil in some cases. Very thin chilled cast iron may be softened somewhat by placing a small amount of sulphur on the place where the hole is desired and then heating to a dull red. This should be done slowly, however.

**Avoiding Scale.** When cast iron is being worked in a lathe or a planer, the point of the tool always should work beneath the scale, which is the outer shell that covers all cast iron as it comes from the foundry. This scale is very hard and brittle and if the edge of the tool is made to work in, or against it, the edge is soon dulled. When the tool works beneath the scale, raising the chip removes the scale.

**Pickling.** All castings that are to be machined to dimensions that are only slightly less than those of the rough castings should be pickled or washed in a solution of sulphuric acid and water, which causes the scale to drop off in flakes and leave the metal bare, unprotected, and rusty. Either submersion or swabbing is effective. After being pickled the casting should be washed in a sal soda solution. A good pickling solution for this work is one part of commercial sulphuric acid to ten parts of water.

## MACHINES AND MACHINE PROCESSES

### ARBOR PRESSES AND GEAR PULLERS

**Types of Machines.** An arbor press is one of the most useful tools for an automobile repair shop. Arbor presses are available

in a number of forms. In the simplest type, the pressing medium is a rod which is forced down by pulling down on the handle which is counter-weighted on the opposite end. By a ratchet principle, the rod is held against the work while another stroke of the handle forces the rod farther down. When the handle is let up to the top of its stroke, the locking mechanism is released and the rod may be pushed up by hand.

Fig. 59. Arbor Press for Automobile Work

There is now on the market a universal press especially adapted for automobile work, Fig. 59. This machine has a capacity of 22 tons and allows a 42-inch clearance for the work. It has two levers, one for high-speed work, geared 1000 to 1, and one for low-speed work, geared 2200 to 1. In the illustration, the mechanic is shown pressing off transmission gears with channel blocking, using the 2200 to 1 leverage. The other attachments furnished with the machine are shown on the floor.

**Uses of Arbor Press.** *V-Block.* For automobile work, a useful part of the arbor press equipment is a V-block, shown on the floor beside the machine in Fig. 59. This block is a receptacle for a great many different kinds of stock.

*Handling Press Fits.* In automobile construction, there are a great many parts which are a press fit into another part. A press fit differs from a sliding fit in that one piece must be forced into another for permanent location while those parts are performing their function; with a sliding fit, one part is located within another so that it may be readily moved, as in a bearing. The arbor press easily handles press fits in replacement and repair.

Where a shaft is a press fit within a gear, that shaft may be pressed into the gear by means of the arbor press. The gear should be located on the bed of the press. If it has a hub, the gear should be supported underneath as close to this hub as possible so there will be no danger of springing the gear. The shaft is then started into the hole; the screw or rod of the arbor press tightens down against it and presses the shaft into the gear. It is well to remember that the available pressure in an arbor press is enough to bend a sizable piece of steel, and with this in view, work should always be very carefully centered and, in the case of shafting, the shaft should be perfectly parallel with the sides of the hole it is about to enter.

*Removing Bearing Bushings.* One of the biggest fields for the arbor press in a garage is in the removal of bearing bushings. There are a great many places about the car where bearings are pressed into their containers, a notable instance being in the springs. Bearing bushings may be very readily pushed out of springs with an arbor press. In most universal joints the steel bushings are pressed in with an arbor press and about the only satisfactory way they can be removed is to press them out with the same kind of a machine.

*Straightening Parts.* Another use for the arbor press is in straightening parts. In the modern automobile, practically all parts which take a considerable amount of strain are constructed from alloy steel. In order to properly prepare alloy steel for severe strains, it must be heat-treated in an accurately calibrated oven to a temperature averaging about 1500° F. Too many repair men make

the mistake of trying to straighten these heat-treated parts in a forge. Once they are heated in a forge, the value of the previous heat-treating is lost and it can only be put back into the metal again in a heat-treating oven.

Furthermore, parts made of alloy steel which have been subjected to the heat-treating process, although capable of tremendous bending strains, may nevertheless be bent without harm to them providing enough pressure is applied. An arbor press capable of exerting a 15-ton pressure can be used for straightening front axles, steering knuckles, and like parts.

The arbor press may also be used for straightening tubing and cylindrical parts, such as torsion tubes and rear-axle housings. In doing this work, a screw press is superior to the kind where leverage alone is the pressure factor, because it permits more careful pressing. With an available pressure of 15 or 20 tons, it is a very easy matter to crack a piece of tubing or a cylindrical part, such as a torsion tube or a rear-axle housing, and great care should be exerted in the bending operation.

**Gear Pullers.** Although the arbor press may be used for gear pulling, there is a simpler device, known as a gear puller. Where gears are fitted to small shafts, they are in a great number of cases made a press fit on the shafting. If one were to attempt to hammer the gear off, he would very likely either damage the teeth of the gear or bend the shaft. A gear puller will remove the gear without damaging any part of the assembly. It is a simple device consisting of a beam at the ends of which two arms are fastened with pins. These arms are constructed with hooks on the ends. Through the center of the beam is a thread cut for the purpose, and in this is a screw with one end shaped to a V and the other end squared to permit the application of a wrench.

In operating, the hooked ends of the two arms are fastened to the back of the gear or pulley. Then the screw is turned down until the V-end fits against the center of the shaft on the opposite side of the gear or pulley to which the hooks of the arms are fastened. Screwing down the screw by means of a wrench will exert sufficient pressure to force the shaft out of the gear.

*Combination Gear and Wheel Puller.* There is now an instrument on the market which is a combination gear and wheel puller, Fig.

60. As will be seen, in this instrument the arms cross like a pair of pliers, and the upper ends of the arms have a number of holes drilled in them. A center block between the arms carries the thread for the screw, as well as a tapped hole on each side. Screws are passed through the drilled holes in the arms at various points and into the tapped holes of the center block, thus giving considerable variation in adjustment for the different sizes of work.

## GRINDERS

**Advantages of Grinding.** Machine-shop grinding operations depend upon the abrasive or cutting qualities of stone, emery, carborundum and corundum, when suitably held and presented to the work. The use of solid grinding wheels has made it possible to attain many refinements in machine construction that would have been impossible without them. It has made it practical economically to finish hardened steel parts that could not possibly be machined with cutting tools in the lathe or the planer, and with the softer materials it has made possible smoother and truer surfaces than can be obtained by any other method.

Fig. 60. Combination Gear and Wheel Puller
*Premier Electric Company, Chicago*

**Types of Grinding.** There are four principal divisions to grinding: hand grinding, tool and cutter grinding, cylindrical grinding, and surface grinding. The two latter classes are never required in repair work.

*Hand Grinding.* Under hand grinding is included all the operations in which the work is held to the wheel by hand or with a rest, as in rough grinding, ordinary lathe-tool grinding, buffing, and polishing. The class of machine used for this work is of the simplest form, consisting of the wheel-carrying spindle mounted on suitable bearings on a substantial head or pedestal. Some machines

of this character carry one wheel, others two. Adjustable rests are provided upon which the work being ground can be steadied. This class of grinders is designed for dry grinding of rough and heavy material, where the danger of overheating the work is negligible.

If the work to be ground is tempered, or is likely to become over-heated, a grinder in which a supply of water is constantly on the rim of the wheel to keep the work cool is used. Buffing heads or spindles usually consist of a standard with a shaft carried on two bearings, the pulley for operating being mounted between the two bearings in a Y-yoke. This shaft usually extends well out from the bearings so that work may be conveniently handled. The ends of the shaft are fitted with wheels having rims of wood, leather, or cloth, which are charged with emery or other grinding material. With the buffer no rest is used.

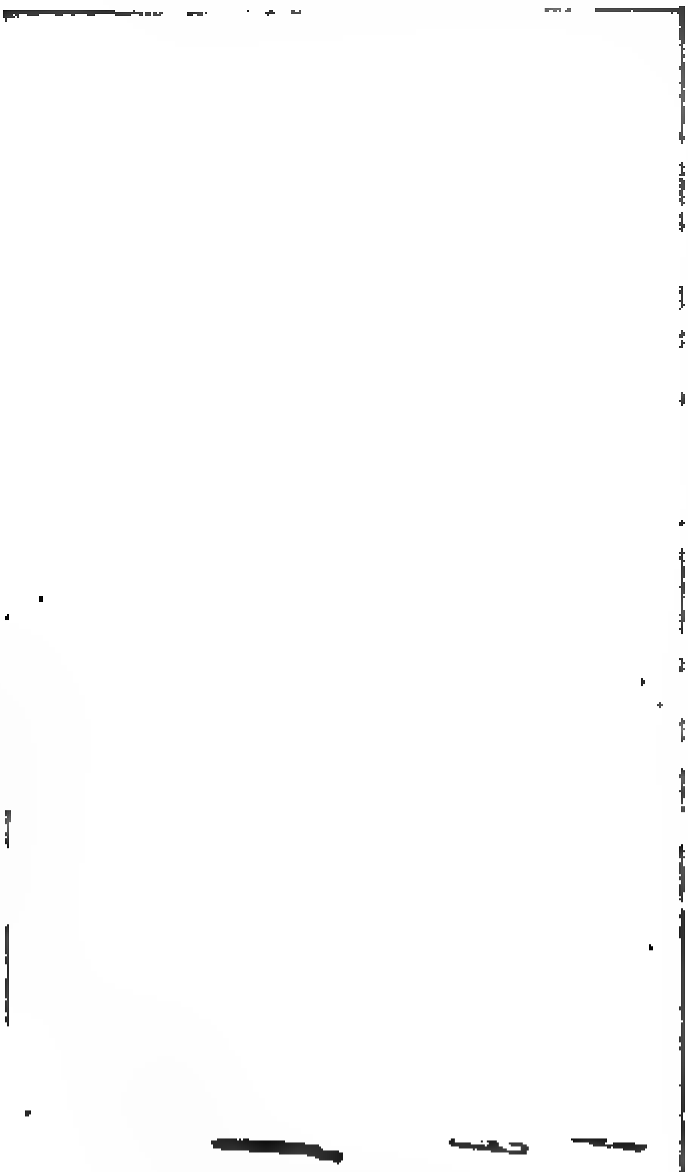


**Fig. 61. Small Milling Machine Tool and Reamer Grinder**
*Courtesy of Cincinnati Milling Machine Company, Cincinnati, Ohio*

**Tool and Cutter Grinding.** For tools and cutter grinding, a better class of grinding machinery is required than for the hand-grinding operations. In this case the term tool refers to drills, reamers, milling cutters, and the finest class of tools, and does not include ordinary hand or lathe tools, which usually are ground on a grinder where the wheel is in constant touch with water.

The Cincinnati Milling Machine Company makes a universal cutter and reamer grinder, shown in Fig. 61. As the name implies, these tools are provided with all necessary attachments for grinding

the cutting edges of all classes of reamers and milling cutters, and in many cases may be used for doing a limited amount of cylindrical grinding, both internal and external.

Cutter grinders have become very necessary to the modern repair shop through the extensive use of the rotating cutter in machining operations and the necessity of keeping these cutters true and sharp. In the grinding of cutters, care and judgment must be exercised, and not until the operator has become thoroughly familiar with all the setting combinations of the machine can he expect to get the best results. Since water is not used on the wheels of cutter grinders, the wheels are usually quite hard and fine, and light cuts

**Fig. 62. Grinding Milling Cutter with Cup Wheel**
*Courtesy of Cincinnati Milling Machine Company, Cincinnati, Ohio*

must be made in order not to draw the temper of the tool at its cutting edge. The cutter support should be adjusted to bear against the tooth being sharpened, and its position relative to the wheel should be such as to give the necessary amount of clearance to the cutting edge. A setup of the above grinder for sharpening a milling cutter with a cup wheel is shown in Fig. 62.

**Care of Tools.** *Twist Drills.* Much care should be taken in the grinding of twist drills to see that the angle and clearance is correct and equal on both sides. Correctly ground drills cut faster, stand up longer between grindings, and produce the proper size of hole. It will be found that a correctly ground drill seldom breaks, since it cuts its way cleanly and does not scrape nor jam as it does when the angle and the clearance are not right.

*Proper Wheels.* Wheels for any class of grinding should be properly adapted to the work as to shape, grade, and hardness. Shape and character of the work determine in any case the shape of the wheel to be used, while the material of which the work is composed, the amount of metal to be removed, and the condition of the finished surface must determine the quality of the wheel. A free cutting wheel which is run at the proper speed and with a light cut is best for accurate grinding, since it removes the metal without pressure and consequently cuts the high spots without heating up the work.

However, if the work is to be very accurate, it is best to use water on the wheel, as a slight temperature tends to have a noticeable effect upon the work. When long cuts are to be taken, it sometimes is difficult to get the wheel to stand up so as to give a parallel cut. Since the harder wheels hold the emery longer, they can be run somewhat slower and they are best adapted for giving cuts of this kind. The wheel should have a wide face and be of large diameter so as to present as many grains of abrasive as possible to perform the required work. It also is necessary to use the coarser feed and lighter cuts in order that the wheel may cover the entire surface before it drops materially in diameter.

Manufacturers of grinding wheels give a table of speeds for wheels of different diameter, but these speeds are not always best suited to the work. All wheels should fit easily, yet closely, on their spindle, to prevent any possibility of cracking, and a soft washer of uniform thickness should be placed between the sides of the wheel and the clamping washer. In grinding long work, it is quite necessary to support the work at one or more points between its end bearings, for otherwise true work is impossible.

## DRILL PRESSES

**Function of Drill Press.** The standard drilling machine, in its various forms, consists primarily of a revolving spindle which carries the cutting tool; a work-holding plate, or table; and a substantial frame connecting the two. Details of spindle adjustment and also of spindle drives and feeds, while they differ in points of detail in the several designs and classes, all bear close mechanical relations to

each other. Boring holes of comparatively small diameter is the specific field for this class of tools, but reaming and tapping these holes are in many cases added to the work of the drill by means of special tools and fixtures, thus taking over the work that at one time was done on the lathe.

**Method of Action.** In the class of drill presses termed standard upright, the feed is automatic, and usually a variety of feed speeds is given as well as an automatic knock-off that stops the work at any desired point. In addition to the automatic feed, both wheel and lever feeds are usually provided. The rack and pinion method of moving the spindle is common to practically all makes and types of drill presses. The spindle usually has its lower bearing in a quill which is given a close sliding fit in the head. The feed rack is secured to the quill. This has particular reference to that type of drill press having a sliding head, the head having a vertical adjustment on the front face of the column to adapt the machine to work of different heights and to drills and tools of varying lengths. The head is counter-weighted so as to make operation convenient. The head can be firmly clamped in any position.

An arm supports the work table and this arm is manipulated by means of a screw and a crank. It can be swung to a considerable angle either side of the spindle and firmly clamped in almost any position. In case the work is too high to be supported on the adjustable table, a lower-base table may be used.

A stationary head usually is found on the smaller machines of this class, all the vertical adjustment being accomplished by moving the table up or down, as required. Such machines are regularly made up to 52-inch capacity, the size indicating the maximum diameter of the work whose center can be reached by the spindle.

In work where small drills can be used, a light machine called a sensitive drill should be used in order to obtain the high speed required and the lightness of parts necessary. Here, the term sensitive commonly means lightness of parts, smooth running, and perfect balance, which enables the operator to judge as to the pressure he is applying to the drill and, consequently, lessens the danger of breaking the drill. Some manufacturers go a little farther and employ at some point in the drive an adjustable friction clutch with which the speed of the drill can be regulated.

**Securing Work.** Securing work on the table of drilling machines requires clamps, bolts, jacks, and blocking, as in other types of heavy machines. The same care should also be exercised in the setting, for true work requires careful setting. The use of a square and surface gage as well as good parallel bars is essential in setting up work for drilling. For through drilling, the work must be located so that the drill in passing through will enter a slot or the central hole on the table. If the work is too large or if for any other reason this cannot be done, then the parallel bars on the table should be used before putting on the work. These should be sufficiently thick to allow the drill to pass through without striking the table.

**Lubrication in Drilling.** Drilling of steel and wrought iron requires lubrication for the cutting tool, while cast iron and brass are drilled dry. Lard oil makes the most satisfactory lubricant, however, its cost usually makes its use prohibitive. The lubricant tends to conduct away the heat generated by the cutting tool and it should be applied directly on the part of the work that is being cut. Some drills have a special reservoir in the head for carrying oil and the lubricant is forced on to the cutting edge.

## POWER HACK SAWS

**Method of Action.** Very general use is made of power-driven hack saws in the automobile repair shop. These machines use the regular pattern of hack-saw blades, which with proper care do a remarkable amount of cutting; the machines require but little attention and when properly adjusted will saw off work reasonably square. There is usually an arrangement by which the machine comes to a stop when the work has been cut and the saw drops through.

**Pressure on the Blades.** When the saw blade is new, the weight on the top of the saw frame should be a little less than after the teeth have become worn, for, when new, the saw bites into the metal considerably faster than after they have become dulled from use. Furthermore, there is danger of stripping the teeth or breaking the blade, especially if the work is of small diameter. A comparatively light pressure permits contact with but a few of the teeth at each point in the stroke. Tubing is very hard on blades and should be cut with a very light pressure and with saws which are somewhat worn. Never use oil on the hack-saw blade.

**Pressure for Different Metals.** It also should be borne in mind that different metals require different amounts of pressure on the saw. Unless one desires to break saws and strip teeth, a close adherence to the following must be observed: Aluminum or any other soft metal of this character cuts twice as easily as cast iron and approximately four times as easily and as fast as steel, consequently the weight on the frame of the saw must be moved forward or backward to give the proper pressure. Perhaps the best point for locating the weight in cutting aluminum is at the extreme outer end of the frame, about the middle for cast iron, and well toward the inner end for steel. Of course, there is no regulation of the backward and forward speed of the hack saw, hence it is necessary to bring judicious use of the weight into play if the life of the saw blade is to be preserved.

Power hack-saw blades should last as long in comparison to the amount of sawing done as the hand hack saw, perhaps longer, if the saw is not called upon to do duty at a faster pace than that for which it was designed.

**Allowance for Cut.** The novice in using the hack saw frequently does not make allowance for the cut but measures off the length of his piece, marking the exact length, and then starts sawing with the blade exactly on the mark. When the piece has been cut off, he finds that it falls short of his measurement, perhaps $\frac{1}{64}$ inch. This shows that allowance must be made for the width of the saw cut instead of sawing directly on the mark, for the $\frac{1}{64}$ inch which the blade removes sometimes makes the piece useless.

## LATHES

**Characteristics.** Of course the most important power machine in a motor-car repair shop is the lathe. In this discussion, the engine lathe only will be considered in its simple form, or modifications of it, as shown in Fig. 63. The lathe is capable of handling a great variety of work. There are four main parts in the ordinary engine lathe: bed *A*, headstock *B*, tailstock *S*, and carriage *X*. The bed is the bench, or foundation, upon which the rest of the machine is supported. Placed on top of the bed are what are known as shears, which are really tracks upon which the moving parts ride. There are two pairs of these shears, and the headstock and tailstock rest upon the inside pair and the carriage on the outer pair. The headstock con-

tains the pulleys and other devices which receive and transmit the power to the work. The tailstock is the holding device for centering

Fig. 63. Typical Engine Lathe
*Courtesy of Reed Prentice Company, Worcester, Massachusetts*

material to be worked upon between itself and the headstock. The carriage carries the tools which perform work upon the material at hand.

the carriage, faceplate, and chuck. In center-rest work, the center rest of the lathe carries one end of the work and the live spindle the other. In carriage work, the work is secured stationary to the carriage and a rotary cutter mounted on the spindle performs the machining. With chucks or faceplates, the work is supported in jaws within a live spindle. A live spindle is one which rotates and is direct driven from the power medium.

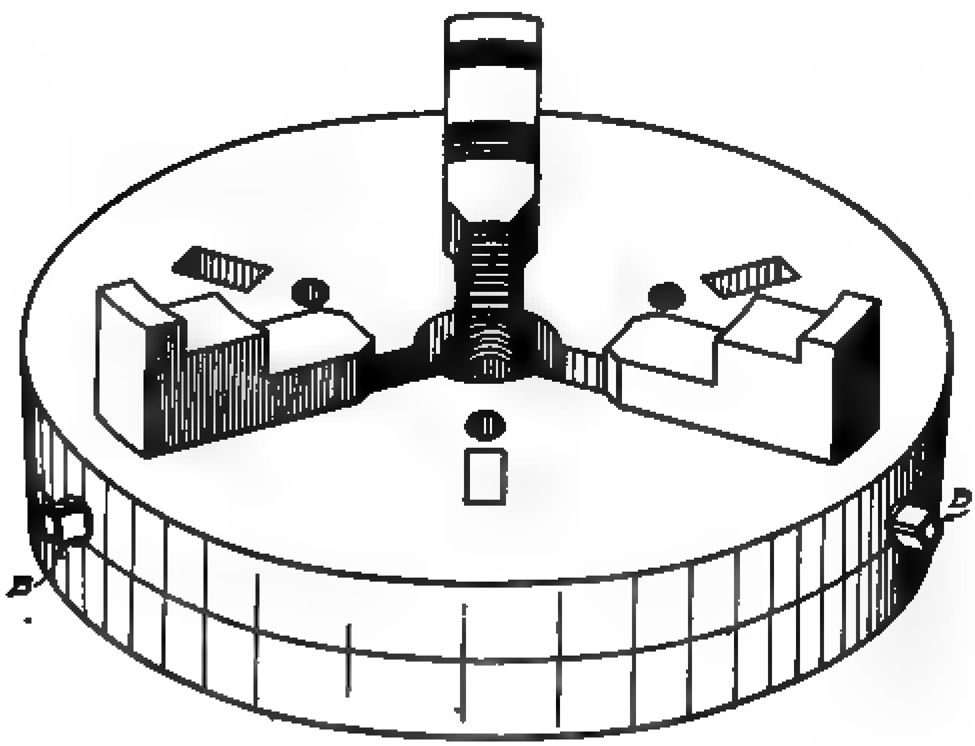



Fig. 65. Combination Chuck

Every lathe should have one or two chucks as a part of its equipment. These are made in two-, three-, and four-jaw types, but the three-jaw type, Fig. 65, is adaptable for most work.

**Simple Lathe Work.** The beginner's job on a lathe is to turn a plain spindle between centers. For example, assume that a bar of 1-inch round steel is to be reduced to a diameter of $\frac{7}{8}$ inch.

*Centering Stock.* The piece to be turned down is first cut to the proper length allowing enough for squaring and is then centered.

Centering means placing V-shaped depressions in the exact center of each end of the piece.

There are some very handy centering tools on the market which are adjustable for different lengths and diameters of stock and afford a quick means of placing an accurate center in each end of a bar. Fairly accurate centering can be done with a center punch and hammer. Each end of the piece must be bisected with two horizontal lines to obtain the center, this being done with a surface gage. Then depressions can be hammered into the ends of the stock by placing the point of the center punch at the point where the bisecting lines cross, which should be the center point of the stock. Another method is to mark the centers, as described, and drill centers into the end in the drill press.

These centers do not have to be deep or wide, but should have just enough of V to afford a firm support for the points of the centers. Where the work is going to consume considerable time and the piece which is being worked is heavy, it is advisable to make deeper centers and cut oil grooves into the sides of them with a cape chisel so that the center may be frequently oiled. In centering the piece, it must be neither a tight nor a loose fit.

*Squaring Off Work.* With the work centered, the ends of the piece are squared off with a cutting tool. This is an operation requiring care. The expert lathe man will square the end to within a very small fraction of an inch of the tailstock center, but will not ruin the center by cutting into it.

*Roughing Cut.* The next operation is the cutting down of the surface of the stock to within about $\frac{1}{32}$ inch of the finished diameter. The depth of each cut, of course, depends on the material which is being worked on. In soft metals, such as brass and aluminum, a fairly deep cut is possible, while in steel it should be around $\frac{1}{32}$ inch. This is a matter which can be determined by watching the action of the tool and examining the point frequently to see what effect the cuts are having on it. This roughing operation tends to work the center into a smooth easy-running bearing.

*Reversing Work.* The work is then removed from the centers and changed end for end. Another roughing cut is made and then the work is ready for the finish cut. It must be remembered that no part of the work shall receive its finish cut until the parts have been

roughed over and the centers have been well worn in. These provisions are necessary for accuracy.

*Finish Cut.* The finish cuts must necessarily be light ones. On the second roughing, that is, the cut which is made after the piece has been reversed, the stock should be cut down enough, so that only one cut is necessary for the finish job.

Mild steel can be cut with cutting-speed settings of 25 to 100 feet per minute, depending on the hardness and quality of the stock. Although too much speed is to be avoided, it is a fact that the beginner generally cuts far too light, not realizing the possibilities in the cutting tool.

If the surface is to be a polished one, the mechanic must make some allowance for filing and finishing with emery. Here is found another beginner's fault in that he generally leaves far too much stock to be filed off. It must be remembered that it is a difficult proposition to file a rotating piece and still keep it cylindrically true. The finishing cut, when filing is to be done, should leave about .003 inch to be filed and smoothed off. This work of cutting down a bar between centers is the elemental training for all between-center work, in fact to a greater or less degree, for all kinds of lathe cutting.

**Boring.** The majority of work done in chucks and with carriage support comes under the head of boring. As work of this kind is usually performed on solid stock, it is necessary to drill a hole sufficiently large to allow the boring tool to enter. This hole can be easily drilled in the lathe by using an ordinary twist drill supported in the tail center. If the work is to be of large size, the taper shank drill is best suited for this work, inasmuch as it readily cleans itself of the cuttings. If the drilling is to be very deep, the drill must be frequently drawn out, cleaned, and oiled, or the generated heat will damage the flutes of the drill.

*Drill and Boring Tool.* The size of drill which one must use for making holes preparatory to boring depends, of course, on the nature of the work. If the work is to be small in diameter and of considerable depth, a drill within one-sixteenth of an inch of the diameter of the finished hole should be used if possible. If the hole is to be of large diameter and shallow, the drill should open a hole large enough to permit the entry of a short stiff boring tool, and this naturally does not have to be very large. There may be obtained boring bars of

universal type which will take a variety of tool shapes. In these the tool is secured in a mortise through the bar by suitable wedges or, more usually, the tool is of round steel fitted into a hole through the bar and secured in position by a set screw. In cylinder boring, or reboring, more than one cutter is generally used inasmuch as a single cutter would be liable to spring the cylinder and gouge the metal. The use of a cutting bore equipped with three cutters gives a tool which will operate steadily and make a very satisfactory bore. As in all cases in lathe work, the finish cuts should always be light ones to insure true work.

**Mounting the Work.** It is more or less of an art to fit a piece, especially an irregular one, into a lathe chuck. No rules can be laid down for this inasmuch as each piece must be centered to take care of its regularity or irregularity in shape. In a good many jobs, the work is of such shape that it cannot be held in a chuck. In such cases, the work may be clamped to the face plate or to an angle plate fastened on to the face plate. This is a setup which requires a great deal of care and patience. In such parts as gear blanks and other pieces having hubs, the work should be chucked on these hubs whenever possible. Work held in this manner will run true if properly bored and turned. It must be remembered that a chuck centers the job. For instance, if one has a piece with a flange and a hub as a part of it, he can have the bore run true with the hub by chucking the work on the hub; but if he desires to have the bore run true with the flange, he should chuck the work on the flange.

**Degrees of Fit between Shaft and Hole.** When a piece of shafting or tubing is to be turned down to fit a certain drilled or bored hole, there are three kinds of fits which apply, viz., working fits; driving, or forced, fits; and shrink fits. A *working fit* is one such as is found in a bearing, that is, the work will be so machined that it will slide easily in the piece. A *driving, forced, or press, fit* is one in which the work is so machined as to require pressure, either by hammering or in an arbor press, in order to get the cylindrical stock into the hole. In automobile construction, a working fit is generally machined so accurately that the difference in diameter between the cylindrical piece and the hole is extremely small, and still a perfect sliding fit is maintained. The importance in fitting bearings is to have the surfaces of both pieces true to one another within .001 or .002 inch.

In accurate work, this agreement runs into ten-thousandths inch. A *shrink fit* differs very little from a driving fit. It must be so machined in both pieces that, when the bored or drilled piece is heated enough to expand it a few thousandths of an inch, it will allow the cylindrical piece to be easily pushed into it. Then when the heated piece shrinks or contracts, a very tight fit is naturally the result. There is one thing to be avoided in making a forced fit and that is the tendency to swage the metal. This is not the case in a shrink fit inasmuch as the piece goes in easily and then the hole closes squarely down upon the center. It is very important in making a press fit that the cylindrical piece be introduced squarely into the hole. In the shrink fit, it is quite necessary that the relative positions of the two parts, one within another, be quickly made because the shrinking takes place rapidly and causes the two parts to lock together. With a forced fit, in which it is contemplated that the parts will have to be separated, the surfaces of the hole and the cylindrical piece are lubricated, thus preventing oxidization of the metals and making it easier to drive out the shaft. The easiest way to do this is to heat the ring, thus expanding it, in the meantime keeping the shaft as cool as possible by pouring cold water over it.

## SHAPERS

**Characteristics.** In many respects the shaper and the planer are alike. The same cutting tools may be used in either and the general principles involved in the operation of these machines are quite similar. However, they differ materially in design; with the planer the work moves to the tool, while with the shaper the tool moves over the work. On the planer the vertical and lateral feeds are given to the tool, while on the shaper the lateral feeds are usually given to the work and the vertical feed to the tool. In what is known as the traverse-head shaper, both feeds are given to the tool and the work is held perfectly stationary. A shaper of standard design is shown in Fig. 66.

**Clamping Work in Shaper.** Proper securing of the work in the vise on the shaper table for planing operations is a most important step in the production of satisfactory work. The variety of work assigned to the shaper is great and the operator will continually find himself with new problems to solve, problems that require the exer-

cising of good judgment and care. In the majority of cases more skill is required in setting up the work than in the actual machining.

In work that is compact and heavy and where the amount of metal to be removed is comparatively small, there is but little danger of springing the work; but if the work is large, of irregular shape, or light, the danger of springing is materially increased. In the first

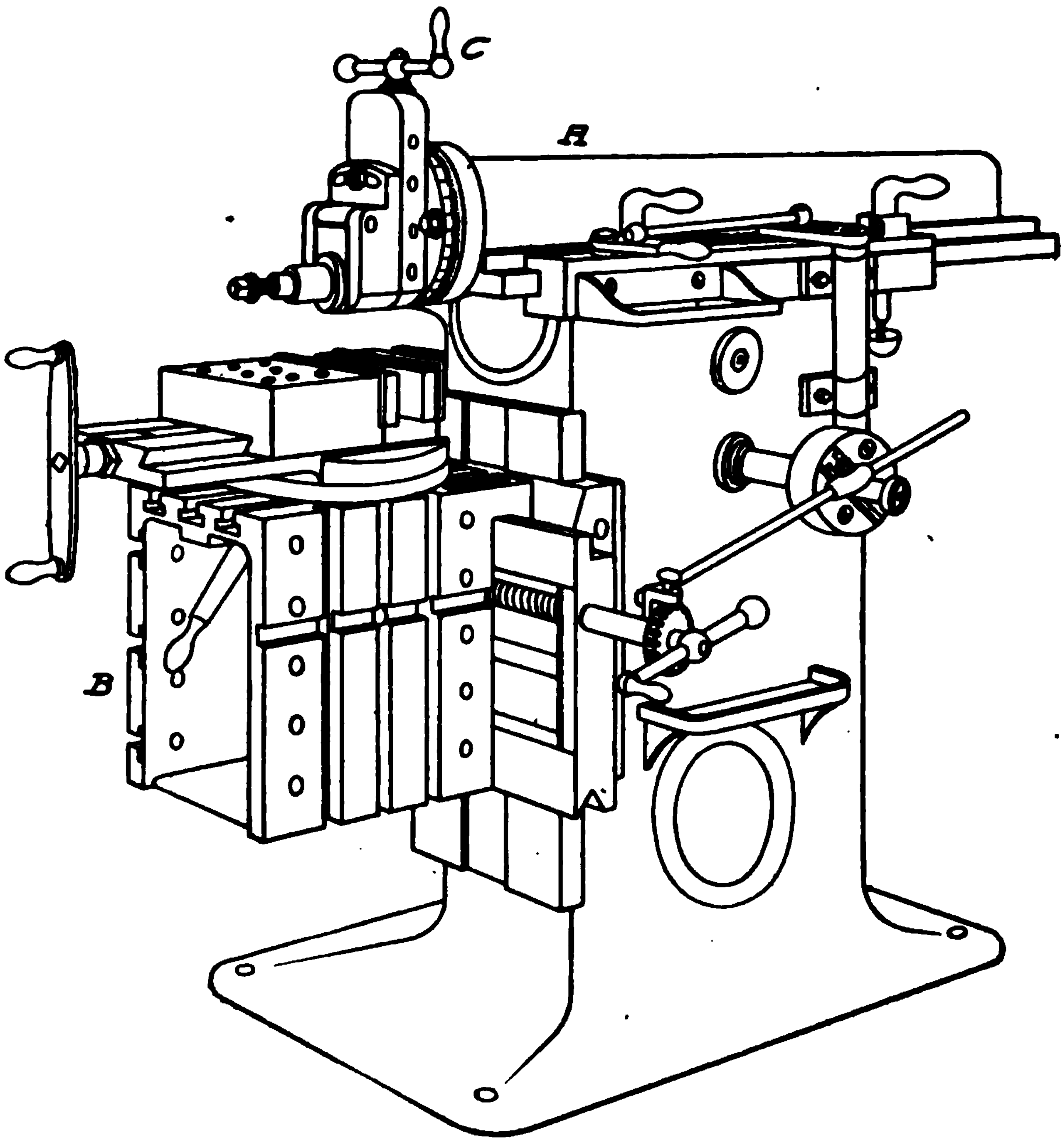


Fig. 66. Typical Pillar Shaper

place, lack of uniformity in clamping distorts the work and throws the machined surfaces out when it is unclamped. Again, the removal of the outer surfaces of a casting or forging, which frequently relieves shrinkage and forging strains, throws the work out of true. The first of these difficulties can be overcome only by using the utmost care in setting up the work, and the second, by first roughing off all surfaces as far as possible before taking any finishing cuts, thus allowing the work, after the roughing, to assume its normal condition.

It is very important that the clamping of the work to the table be done with due consideration for locating the points of clamp pressure directly over the points of support. The supports should be firm and bear about equally on the work and the table. If only a thin shim is required to level up the work, this should be of metal in preference to card board, leather, or any compressible material which will allow the clamp to spring the work. Good blocks and parallel bars are indispensable in the shaper and planer outfits. For work where the points of support vary in height, leveling wedges and small jack screws are excellent, as they can be adjusted quickly to any desired height. These wedges, especially if any single wedge is used, should have only a very slight taper.

**Operation Suggestions.** When it comes to operating the shaper, the beginner should keep a few points closely in mind. Not all geared shapers have a fixed length of stroke, the depth of the cut and the speed of the countershaft affecting in a certain degree the points at which reversal takes place. Some allowance must, therefore, be made for the overtravel of the tool. An excessive amount of overtravel, however, means a large loss of time. Roughing cuts should be as heavy and with as coarse feeds as the machine will conveniently handle and as the strength and character of the work will permit. First, before planing side surfaces, see that the top of the tool box is inclined from the work. This allows the tool to swing out and clear the work surface on the return stroke. If it is not inclined, the point of the tool drags hard on the work surface and, should it be inclined to the wrong side, the tool will swing into the work and do damage. Raising the tool clear of the work on the return stroke preserves the cutting edge. Means are often arranged for accomplishing this automatically.

Keep the cross-rail clamped firmly to the housing, when in use, and parallel with the table. Before putting in the feed, see that the feed gear is on the right spindle, as otherwise the tool may start up or down when it is intended to move across the work. As there is usually more than one way to do a certain piece of work, you should study which is the best way to do it. Those factors that have a great deal to do with turning out quality and quantity work are the manner in which the work is set up, the kind of tools and the way they are ground, as well as the efficient handling of the machine.

## MISCELLANEOUS EQUIPMENT

**Milling Machines.** Although the milling machine is not an essential part of the well equipped repair shop, it is really a necessity in a large shop which does building and rebuilding and all kinds of machine work. In its elemental form the milling machine is made up of a rotating cutter which is held in one plane and a moving bed which carries the work under the cutting edges of this cutter. If one is to thoroughly familiarize himself with one of these machines, there is so much to learn in the setting and manipulation that it is hardly practical to try to give a detailed list of instruction herein. Therefore, only a brief description of the machine will be given. If a man has no idea of the operating principles of a milling machine, the quickest and best way to familiarize himself is to appeal for instruction from a man who knows how to operate this machine. The milling machine is a much more accurate tool than a shaper inasmuch as it cuts stock off with one sweep where a planer requires several sweeps with new adjustments for each sweep if accurate work is to be done.

*Types.* The plain and universal milling machine of the column pattern are the ones generally used for repair-shop work. In this machine, the upper portion of the column carries the spindle and cone, this spindle being back-geared in the same manner as is a lathe. The outer end of the spindle is supported by a suitable overhanging arm. The work table is adjustable vertically and horizontally, these adjustments being made by means of screws which operate with wheels and handles. There is a wide range of cutting speeds provided in the feed mechanism.

*Cutters.* Milling machine cutters are produced in a variety of forms designed to take care of different kinds of work. One of the most commonly used cutters is the axial type which has teeth on the cylindrical surface only. In the small cutters, these teeth are straight across the surface, and in cutters above 1½ inch they are cut spirally. Another and similar type of cutter is the plain milling cutter with nicked teeth. This has merit in being able to take a deeper cut inasmuch as the chips are broken up by the nicked cutting teeth.

The narrow cutters come in what are known as straddle-mill, radial-face, and side cutters. Another type is the end, or shank, milling cutter which is similar to the radial-mill except that it has its independent shank. These are generally used for small milling work,

and frequently the teeth are cut spirally. When one desires to do slot milling at the end of a shank cutter, there is a special type provided, having radial teeth on the inner ends provided with cutting edges, which enables them to cut their way out when moved along the work. For cutting standard T-slots, there are special tools provided having a shank end and inasmuch as they work with the shank vertical to the slot, it is necessary that the center portion be cut away first to allow the narrow end of the shank to pass between. For annular cutting, there is a variety of tools built up to take care of every kind of this work. Probably the most economical for milling tools are those having removal cutters which may be replaced when worn out.

**Planers.** It is only in the very large repair shops that the planer will find use. As the name indicates, the planer is used for finishing flat surfaces. As has already been said, the planer resembles the shaper, and no further description will be given.

# REVIEW QUESTIONS

# REVIEW QUESTIONS

ON THE SUBJECT OF

# GASOLINE AUTOMOBILES

## PART V

1. Explain the action of the Winton steering gear.

2. Describe the action of a correct steering arrangement in turning a corner.

3. What are the double requirements of a correct steering gear?

4. Name the different forms of steering gears now in use and describe one form.

5. Why is the worm utilized in nearly all steering gears?

6. Give the special advantages of the Hindley worm over other forms.

7. How does the drag link used in the Ford steering gear differ from conventional designs?

8. Give the test for backlash in an irreversible type of steering gear.

9. Why is it necessary to use at least one universal joint in a steering rod?

10. Discuss steering in 4-wheel drive types.

11. What is the difference between the Elliott and the Reversed Elliott front axles?

12. Describe the Marmon self-lubricating axle.

13. Why are sub-frames used?

14. Discuss wood frames and name American car that has its frame made of wood.

15. What is the peculiarity of the Marmon frame?

16. Explain the Hotchkiss drive.

# REVIEW QUESTIONS

ON THE SUBJECT OF

# GASOLINE AUTOMOBILES

## PART VI

1. Discuss the advantages of flexible joints when used in place of universal joints.

2. Give the advantages and disadvantages of the shaft drive

3. Why are torque rods necessary?

4. Into what classes may rear axles be divided?

5. What percentage of 1917 cars use the three-quarter floating axle?

6. Describe the rear-axle construction of the Case car.

7. Explain the action of a gearless differential.

8. How may a sagging axle be adjusted?

9. How many sets of brakes should be used on a chain-driven car?

10. Describe the action of the brake used on the Knox tractor.

11. Why have substitutes been sought for the ordinary differential?

12. What are the advantages of silent chains?

13. What system of final drive is used in the Metz?

14. How may chattering be eliminated in internal-expanding brakes?

15. What is meant by "checking up" axles?

16. What are the advantages of double-brake drums?

# REVIEW QUESTIONS

## ON THE SUBJECT OF

# EXPLOSION MOTORS

1. Name and describe the essential parts of an explosion motor.

2. Name the various accessories necessary to the operation of an explosion motor.

3. How is the fuel gotten from the fuel tank into the engine cylinder; how is it exploded?

4. Describe (a) the four-stroke cycle; (b) the two-stroke cycle.

5. Explain the essential points of difference between the motors used in automobiles, boats, motorcycles, aeroplanes, and stationary work.

6. Explain and give reasons for 6-cylinder firing arrangements.

7. What are the advantages and disadvantages of 4-cylinder and 6-cylinder motors? Compare the two types.

8. Explain what knowledge may be secured from an indicator and manograph diagram and to what purpose it may be put. Also explain how to make use of the diagram in finding the i.h.p.

9. Assume that Fig. 47 is the diagram from a 4-cylinder 4-cycle motor, 107.6 lb. m.e.p., 650 r.p.m., $4\frac{1}{2}$-inch stroke, $4\frac{1}{2}$-inch cylinder diameter, 90 per cent mechanical efficiency. Determine (a) i.h.p., and (b) b.h.p.

10. Explain fully the effect of scavenging.

11. Explain all points of difference between compression in the two-stroke cycle and the four-stroke cycle.

12. Why does increased compression pressure increase the efficiency of an engine?

13. State the advantages and disadvantages of the 2-cycle and the 4-cycle engine.

# REVIEW QUESTIONS

ON THE SUBJECT OF

# BUILDING, EQUIPPING, AND RUNNING A PUBLIC GARAGE

1. What power machines are most necessary for an automobile repair shop and what are the uses of these machines?

2. Explain the basis of calculation of a garage proposition as an investment.

3. Analyze the revenue from all sources for a garage holding, say, 100 cars.

4. Give a good layout for a one-story garage, size 75 by 200 feet, giving the location of necessary equipment and the most efficient arrangement of cars.

5. What building equipment is necessary in a 3-story garage?

6. Discuss elevators vs. ramps.

7. Under what circumstances is a garage justified in carrying accessories and selling cars?

8. Explain how a garage owner is going to settle the question of exclusive storage of cars, as compared with part storage space and part sales space. Give figures to justify conclusions.

9. Give the points necessary to consider in determining a good location for a garage.

10. Is the square shape of building economical for a garage? Explain, and give the best arrangement for a square floor plan.

11. What is the best use to which a basement in a garage can be put?

12. Give a sketch showing a safe arrangement for the gasoline supply.

13. What should be the specifications for a garage as to fireproofness?

# REVIEW QUESTIONS

ON THE SUBJECT OF

# SHOP INFORMATION

---

1. Explain the process of scraping a crankshaft bearing.

2. What tap and die equipment should be found in a good automobile repair shop?

3. Give the most important parts of a lathe and the accessories necessary for ordinary shop operations.

4. What other machines besides the lathe are useful or necessary in a repair shop?

5. Give the process of mounting a clutch leather.

6. Describe how a cylinder is lapped by means of a jig in a drill press.

7. Give the principle of action of a micrometer caliper and show the uses to which the instrument may be put.

8. Give the names of the different kinds of files used in repair work.

9. How are piston rings fitted and put in place on the piston?

10. What fluxes are used in soldering the various common metals in the repair shop?

11. How would you cut a keyseat in a piece of round steel shafting?

12. Give the number of flutes advisable on a reamer and state your reasons.

13. Give a diagram showing how to calculate the setting for the graduated circle on the lathe slide rest to produce a given taper. Explain.

# INDEX.

# INDEX

*The page numbers of this volume will be found at the bottom of the pages; the numbers on the top refer only to the section.*



*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*

*Note.—For page numbers see foot of pages.*